POWER PLANT ENGINEERING

GENERATION, TRANSMISSION AND UTILIZATION OF STEAM, ELECTRIC, DIESEL AND HYDRAULIC POWER

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A. W. KRAMER, Electrical Editor RICHARD H. MORRIS, Engineering Editor.

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In the good old summer time.

Photo by Fred Hess & Son.

TIME WAS

WHEN the annual convention of the Electric Utility industry at Atlantic City in June was something to write home about. It was a gorgeous event, something just short of an epic—a glittering pageant of social splendor, good fellowship and unrestrained enthusiasm. True, we seem to recall some business sessions and, come to think of it, there were usually a few technical sessions tucked away in some obscure corner of Capt. Young's Million Dollar Pier, but nobody really took these things seriously. Out in front, in the great ballroom was Paul Whiteman, B. A. Rolfe or Vincent Lopez with super-augmented orchestras, organizations for the mass production of syncopated rhythm. Our memory also carries pictures of Helen Morgan, Julia Sanderson, Frank Crummit, Jessica Dragonette, Albert Spaulding and all the other illustrious stars of the stage and concert world whose presence graced the glittering ballroom. And there was Public Policy night at which some bigwig would be awarded medals after which there would be dancing. Dancing every night was the rule. There were other things too that seem to haunt our memory—things unreal that had to do with music, soft moonlight and the gentle swish of the Atlantic as the waves crept up the beach—a sort of lost consciousness of having been fearless and eternal.

And why not? Had we not reason to be fearless? Were we not sitting on top of the world? As we recall, Midwest Utilities stock had not quite touched 500 but we knew that it was merely a question of time before it would. And were there not two cars in most garages—not always paid for, perhaps, but they were there and soon, we knew, all garages would have two cars. And had not war been outlawed? The Kellogg pact was in the making and soon some 40 nations would sign it.

Things looked rosy. The utilities had little to worry about. The Industry was in its ascendency, power and super-power stations were springing up like mushrooms from coast to coast, systems were being combined and integrated, whatever that meant, and practical public ownership was being attained by the sale of great blocks of stock to the public. There was no T.V.A. to give utility executives sleepless nights, no S.E.C., in fact no E.E.I., and the term New Deal still had significance only with respect to cards. Those were the happy days!

A great deal of water has passed under numerous bridges since those days and many of the bridges have been washed away. About the only things that remain unchanged are the waves breaking upon the beach at Atlantic City. But the Utility men still have conventions and during the first week in June they will gather at Atlantic City as of old. True, the glamour of old may be missing and there may be less backslapping, but it will be a more wholesome meeting as far as business and technical matters are concerned and a large attendance is expected. In view of the criticism, just or unjust, to which the utilities have been subjected, the Utility industry today has its feet much more squarely on the ground than it did in the old days and those who guide it are united in a common effort to promote and protect their interests and constitutional rights. If the E.E.I. Conventions of the last few years may be regarded as a criterion, this should be an interesting meeting. Whether one is directly associated with the utility industry or not, its welfare is of importance to all of us.

While complete details of the convention have not yet been worked out, a brief account of the program so far as it has been disclosed is presented on page 390.

WITH THE EDITORS

Brains and the Power Plant

BACK of every power plant are the brains of an organization of men who have worked out the entire project from the conception of the idea that a power plant has a justifiable place in the social and economic well-being of the community, through the legal phases of securing rights and franchises, the financial negotiations to obtain the necessary capital for carrying the project through to the point where it is self supporting, the design of the plant as a whole and the equipment to be installed, the plant construction and erection of equipment, the efficient and safe operation, and finally to the entire sales problem of disposing of the product at a profit that will justify the undertaking. Thus are combined the legal, financial, engineering and sales efforts of many specialists to supply a community with that service called utility electric power.

The machinery itself can be nothing more than a tool, albeit a very important one, in this service to a community, but what could this service be without the brains of men to guide and direct it? Power plants do not grow and yield products from a physical seed, like grain in the fields or trees in an orchard, but are definitely products of the intellect, mentally conceived and put into physical form through the labors of men aided by machines and materials.

Power plant machinery probably comes as near to running itself as does any machinery now employed in industry. In fact a number of hydroelectric and internal combustion engine plants are in continuous operation with only occasional attention from an engineer. By such painstaking design and construction, manual labor has been reduced to a minimum in the operating schedule of the power plant. Muscular strength and skill have given way to automatic or manually operated controls with an extensive array of instruments and records used in the maintenance of safety and economy. The plant has thus become a product of scientific development and its satisfactory operation depends more upon the mental ability than the physical skill of the operating personnel.

Utility companies as a whole have recognized the changes in the character of the required operating staff which have been taking place over the past generation, with the result that fuel requirements per unit of output have been more than halved in the leading plants. It is in the smaller industrial and institutional plants, where the management still considers the work of the man in charge of the plant as manual labor, that greatest economies are possible. Power generating equipment is a tool which, in the hands of a master, is a safe and economical servant. When, however, mere routine takes the place of intelligent operation of this equipment, dangerous as well as wasteful conditions are almost certain to develop, even with the most carefully designed and manufactured equipment.

Numerous attempts have been made to grade engineers, particularly where licenses are required. Here, of course, the tests are conducted primarily for the purpose of determining whether the applicant is sufficiently familiar with power equipment to insure its safe operation. This, however, is only a part of the qualifications that go to make a successful power plant engineer. Economy of operation is not necessarily an accompaniment of safety and seldom is this phase of an engineer's work made a part of a license examination. The most effective methods of managing men working under the engineer's direction is given no consideration by the license examiner. Nor do license examinations touch on the sales ability of the applicant to secure appropriations for desired equipment for the power plant.

These statements are not made with the idea of criticizing license laws, as they have been and are a potent force in developing a high standard of personnel in power plants as well as increasing the public safety of industrial establishments, and in most cases the laws and ordinances governing engineers' rights to operate equipment have gone about as far in their restrictions as our state constitutions will permit. Like specifications for equipment, however, license examinations can cover only the minimum requirements, any additional qualifications may be considered as individual characteristics difficult to measure and evaluate but nevertheless they spell the difference between modern and antequated operating methods.

Personal characteristics enter so largely into an operating engineer's work that it is almost impossible to predict what his reactions will be under trying or unusual circumstances. This is one of the reasons why executives invariably insist upon long experience as a qualification for responsible positions, in order that they may observe reactions as they occur or secure the benefits of the observations of others familiar with the man's work.

Too often employees in power plants are themselves confused as to the status of their occupation. Some consider it a trade, others a profession. A trade is defined as a pursuit requiring manual or mechanical training and dexterity, while a profession is a calling in which one professes to have acquired some special knowledge used by way either of instructing, guiding, or advising others or of serving them in some art. The pathway to a profession frequently leads through a trade and the practice of a profession may often require the services of tradesmen but as a rule a man with professional qualifications is not using his most valuable talents when doing the work of a tradesman. The employee in charge of the operation of a power plant, be it large or small, is engaged in professional work, whether he is qualified or not.

Safety and economy demand that plant owners and executives recognize the fact that the operation of a modern plant requires the exercise of more brain than brawn and that the men who qualify for such positions are as highly specialized as lawyers, doctors or other professional men.

DRESDEN STATION

Dresden Station is the new steam-electric generating station of the New York State Electric and Gas Corp. designed and constructed by The Utility Management Corp. formerly the E. M. Gilbert Corp. It is located at Dresden, N. Y., on the western shore of Lake Seneca. The initial installation involves a single 20,000-kw. turbogenerator but provision is made for the installation of future units to give the ultimate station a generating capacity of 90,000 kw.

DESPITE the considerable activity in the power industry in recent years, brand new central stations are still relatively few and far between, so much so that the opening of a new station becomes an event of more than passing interest. For central stations, though they may start out small, have a way of growing and as they grow they become elements of increasing importance in the national power scheme. Today, the construction of a central station is no longer a device resorted to to meet the power requirements of the local community; it represents the establishment of a power center, selected because of its peculiar advantages and its relation to other power centers with which it is intimately connected. It is not an entity in itself but an important element of a larger system. This was particularly true in the case of Dresden station to be described in this article.

For several years, the installation of additional steam generating capacity was contemplated for the generating system of the New York State Electric and Gas Corp. which serves the central part of New York state. The decreased power demand during the depression postponed the installation but with the increased output in the years 1935 and 1936, it was found that additional capacity would be required in 1938. The Utility Management Corporation, formerly the E. M. Gilbert Engineering Corporation, made a preliminary study, and was put in charge of engineering, design and construction of a new plant to be built at Dresden.

The accompanying map shows the central part of the system of the New York State Elec. & Gas Corporation. The system has a steam power station at Binghamton with 53,000 kw. capacity, one at Elmira of 23,500 kw. capacity, and a steam heating and generating plant at Hornell of 1500 kw.

Besides these steam generating stations, the system

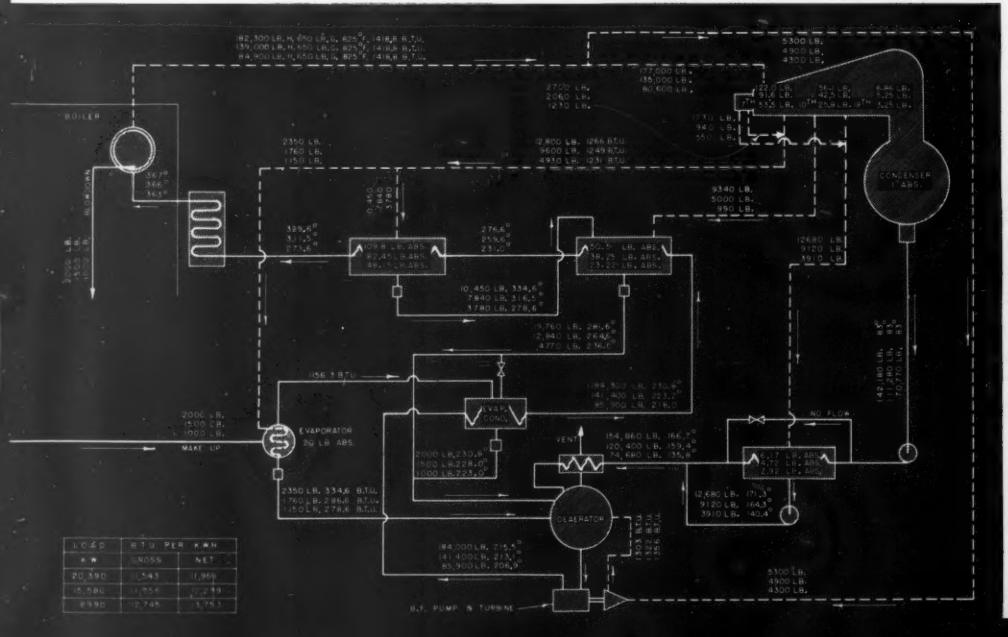


Fig. 1. This heat balance diagram shows the cycle of power generation. The Utility Management Corp. has, for years, stressed the importance of effective deaeration, especially for plants operating at high pressures and temperatures. The deaerating heater, therefore, is operated with exhaust steam from the boiler feed pumps at slightly above atmospheric pressure, independent of variations in pressure at turbine bleed points with changing loads

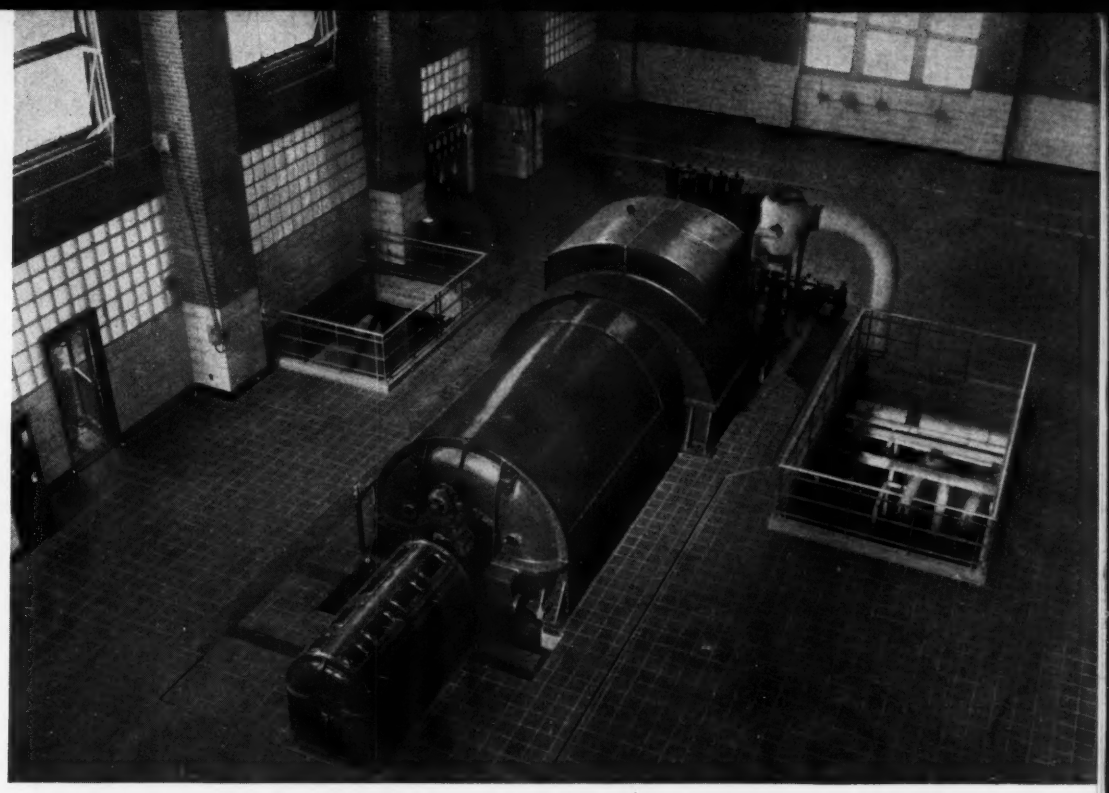


Fig. 2. A view in the turbine room at Dresden Station looking down on the smooth, streamlined 20,000-kw. turbine unit. Instruments on the panel board at the extreme left keep a continuous record of the eccentricity and vibration amplitude of this machine

has hydro plants at Seneca Falls (8000 kw.), at Waterloo (1920 kw.), and at Owego (900 kw.).

It will be seen from this map that in order to obtain a well-balanced system, additional capacity should be installed at the western end of the section, and it was decided to build a new plant on a site selected near Dresden on the western shore of Lake Seneca with rail facilities, and an ample supply of cooling water from the lake available. Dresden, as a matter of interest, is a little hamlet, but it was the birthplace of Col. Robert Ingersoll.

A study of load growth indicated that 20,000 kw. of additional capacity was needed. Accordingly, the new plant was designed for the installation of 20,000 kw. for the first unit, but with provision for the installation of future units of up to 35,000 kw. capacity, each with an ultimate station capacity of 90,000 kw.

In determining the steam conditions, it was felt that with present-day materials, a steam temperature of 825 deg. F. can be handled without difficulty. With this steam temperature at the turbine inlet, and allowing a moisture content of not over 10 per cent in the turbine exhaust to avoid excessive blade corrosion, the steam pressure at the turbine throttle was determined as 650 lb. per sq. in. gage. With the boilers operating at 700 lb. gage working pressure, and a total superheat of 825 deg. F., the boilers, superheaters, piping and turbine can be held within present design standards, allowing high economy with low investment costs.

Details of the Heat Cycle

The accompanying heat diagram shows the cycle of generation. The Utility Management Corporation has, for years, stressed the importance of effective deaeration, especially for plants operating at high pressures and temperatures. The deaerating heater is, therefore, operated with exhaust steam from the boiler feed pumps at slightly above atmospheric pressure, and independent of variations in pressure at turbine bleedpoints, with changing load.

One low pressure heater is installed, taking its steam from the eighteenth stage turbine bleed point. A Minneapolis-Honeywell Control, actuated from the deaerating heater pressure, bypasses a certain amount of feed water around this heater so as to insure a definite temperature and efficient deaeration in the deaerator, with variation in the amount of exhaust steam required.

Two high pressure bleed points are provided, one supplying steam to the tenth stage heater, the other supplying steam to an evaporator and the seventh stage heater. An evaporator condenser is inserted between the deaerating heater and the tenth stage heater.

Two Boilers for Flexibility

In order to obtain more flexibility in operation with the first generating unit installed, it was decided to install two boilers each for 110,000 lb. capacity operating at 700 lb. per sq. in. gage working pressure.

These boilers are Foster Wheeler Co. units of standard three drum design with convection superheaters and watercooled furnace walls. These superheaters are designed to superheat the steam to 825 deg. total temperature. A superheater bypass is arranged with a motor operated butterfly valve in the bypass duct leaving the boiler. This valve is regulated by push-button control from the boiler board. The economizers are comparatively small due to the high preheat of the feedwater and are of conventioual design.

The tubular airheaters are arranged so that the tubes can be lowered vertically for cleaning, inspection, or repairs.

The boilers are designed for pulverized coal firing with one unit pulverizer of the conical ball mill type for each boiler. Two coal burners with inserted re-

movable oil burners for starting up are provided for each furnace. The arrangement of the equipment is shown in the accompanying drawings.

Unusual Provision for Starting Up

An interesting feature is the arrangement for starting up a boiler. In order to cool the superheater sufficiently during this period, steam has to be bled from the superheater. In order to save the condensate from this steam, which amounts to about 20,000 lbs. per hr. and avoid excessive noise from blow-off to atmosphere or blow-down tank, this steam is led through a 2 in. line into a jet condenser head on top of a 15,000-gallon boiler feed storage tank in the basement. When steam is bled from the superheater, a recirculating pump, under the boiler feed tank, pumps the stored water through a heat exchanger into the jet condenser head, which condenses the steam from the superheater entering the tank.

pressure cylinder. The direct-connected generator is designed for 20,000 kw., 80 per cent power factor, 13,200 v., 3 phase, 60 cycle, 3600 r.p.m. with 250 v. main and pilot exciters.

A motor-driven turning gear with separate oil pumps, for starting up, is provided.

Instruments are installed for measuring eccentricity and vibration amplitude of the turbine unit, with the recorders arranged on a separate two-panel instrument board in the turbine room.

The built-up steel plate exhaust end is welded to the extended neck of the hung condenser in the field. Great care was taken to make this weld a perfectly tight job, without causing undue stresses or distortion. To facilitate this, a 1 in. wide horizontal strip was welded to the top of the condenser neck, and the exhaust neck of the turbine was then welded to this strip.

The condenser is a Westinghouse two-pass condenser with divided water boxes and arsenical copper tubes

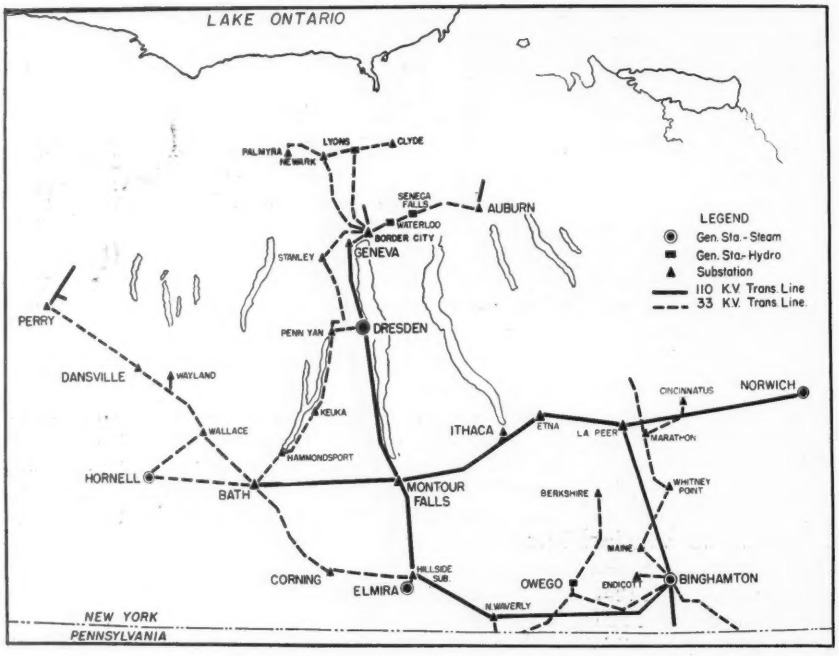


Fig. 3. This map shows the central part of the system of the New York State Electric and Gas Corporation. The system has a steam plant at Binghamton with 53,000-kw. capacity, one at Elmira with 23,500-kw. capacity and a steam heating and generating plant at Hornell of 1500 kw. Besides the steam generating stations the system has hydro plants at Seneca Falls (8000 kw.) at Waterloo (1920 kw.) and at Owego (900 kw.) Now, an additional 20,000 kw. has been installed at Dresden

For cooling the recirculated feed water from 212 deg. F. to 100 deg. F., cold water from a hydrojet pump is passed through the heat exchanger. The operation of this equipment has been very satisfactory, and excessive noise from blowdown when starting, has been eliminated.

The two boiler feed pumps are each built for a capacity of 250,000 lb. per hr., and direct-driven by turbines operating at 650 lb. per sq. in. gage, 825 deg. F. and 2 lb. per sq. in. back pressure at 3500 r.p.m., and exhausting into the deaerating heater. A motor-driven boiler feed pump of 50,000 lbs. per hr. capacity is installed for starting up.

The turbine is a General Electric unit designed for operation with steam of 650 lb. per sq. in. gage, 825 deg. F. at the throttle exhausting at 1 in. Hg. absolute, with provisions for bleeding at three stages. It is a tandem compound double-flow unit, with eighteen stages in the high pressure cylinder and a double flow three stage low rolled in at both ends. The condenser is served by two vertical propeller type circulating water pumps, each serving half the condenser. A unique feature is the design of two elbow reversing valves, which allow reversal of the circulating water flow through each condenser half by turning the valve over a 60 deg. arc. To accomplish the same with conventional valve arrangement, 8 valves would have to be operated. Besides the elimination of a number of gate valves, the installation of the reversing valves greatly simplifies the piping.

Electrical Features

The generator leads are connected to a general bus on an outdoor steel transformer structure through an oil circuit breaker. The power bank consisting of 4-8333 kv-a., 13,200-33,000-66,000/114,000 transformers, connect to the general bus through an oil circuit breaker.

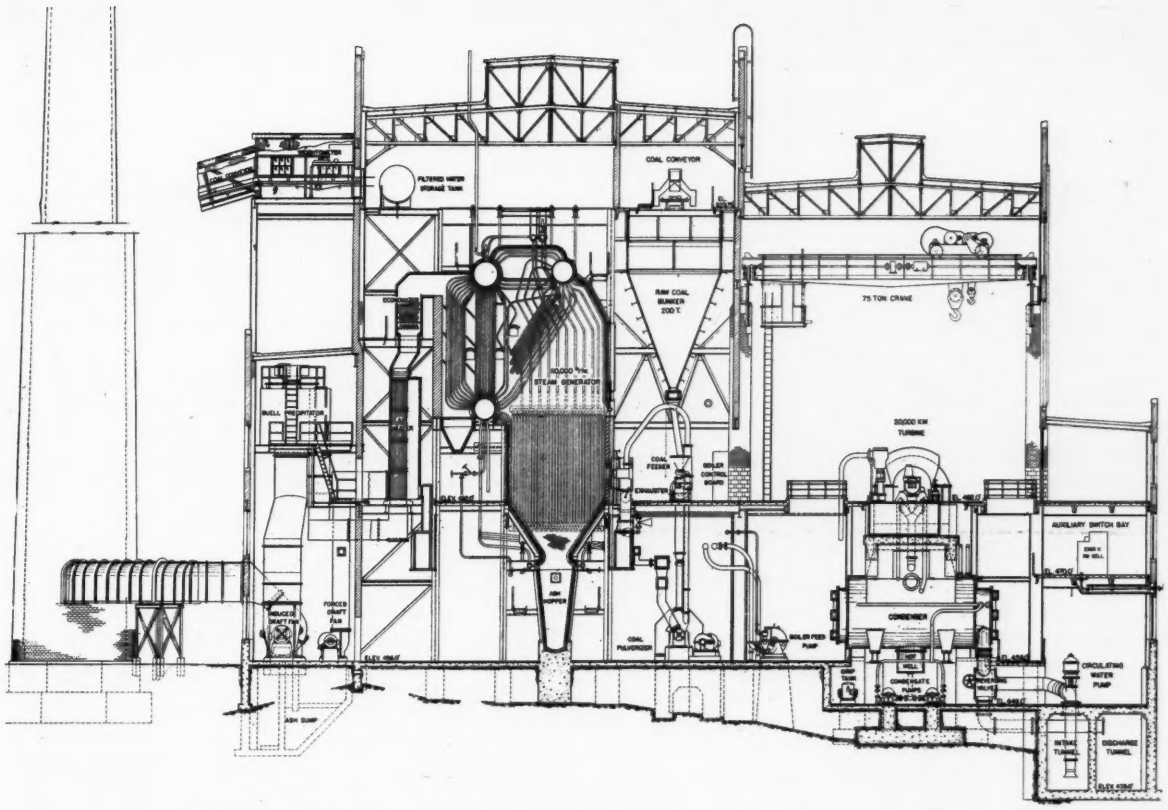


Fig. 4. Cross section through Dresden Station showing the general arrangement of equipment

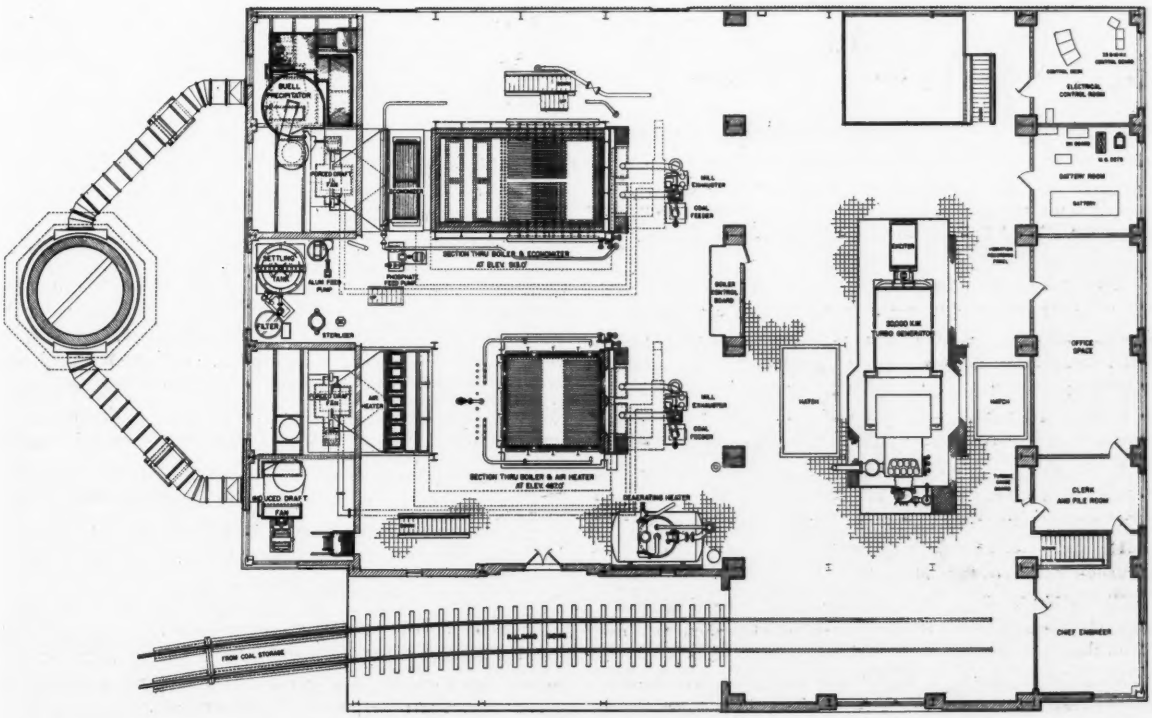

ELECTRICAL CONTROL ROOM
BATTERY ROOM
OFFICE SPACE
CLERK AND FILE ROOM
CHIEF ENGINEER
BOILER CONTROL BOARD
20000 KW TURBO GENERATOR
SECTION THRU BOILER & ECONOMIZER AT ELEV. 513'0"
SECTION THRU BOILER & AIR HEATER AT ELEV. 487'0"
FROM COAL STORAGE

Fig. 5. Plan of operating floor (elevation 482'0") and a small section at elevations 487'0" and 513'0"

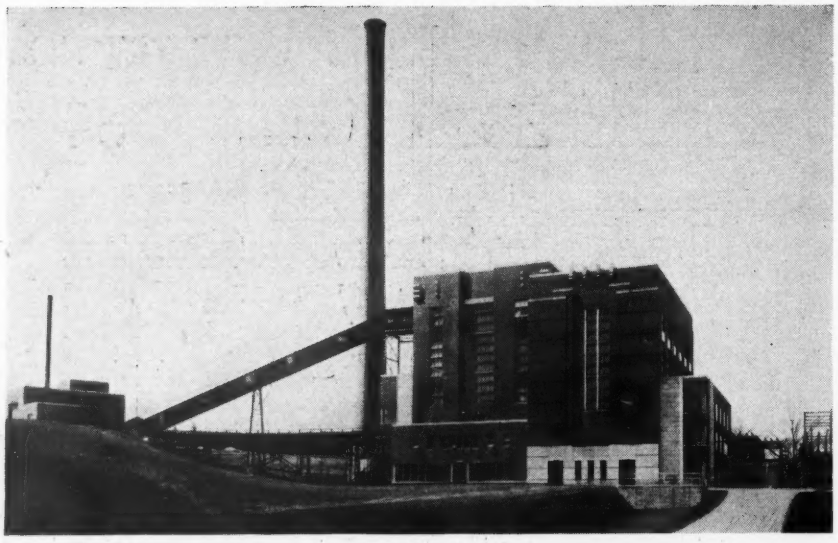


Fig. 6. Dresden Station. The small building at the left houses coal preparation equipment and two small hand fired boilers for raising steam to thaw out cars of frozen coal in winter

One transformer will serve as a spare for this bank and the bank for No. 2 unit in the future. Provision has been made to install a 33 kv. circuit in the future.

The 114 kv. windings are connected through disconnecting switches to the main and inspection busses on the 114 kv. switching structure, which is located approximately 1000 ft. from the station. Provision has been made for installing a circuit breaker in the future. Two outgoing 114 kv. lines are provided with oil circuit breakers and air break switches for bypassing the breakers for inspection. Directional distance and ground protection are provided on each 114 kv. line.

Station Service

Three 1250 kv-a. 13,200-2,300 v., three 200 kv-a., 2300-230/115 v. and one 75 kv-a., 2300-230/115 v. transformer are used for station service and lighting. They are located in the outdoor transformer structure. These 1250 kv-a. transformers are tapped directly off the generator bus through disconnecting switches.

Another bank of three 50 kv-a., 2300-230/115 v. transformers serves the coal handling equipment.

All the station service banks are large enough so that two transformers in open delta will have sufficient capacity to carry the essential station auxiliaries.

Two sections of Metal Clad Switchgear units are used for the 2300-v. cell structure. The main section serves all the auxiliaries for the turbine and boilers. The other section serves the 230-v. station service and coal handling transformers. This section will also serve as a tie between the main sections in the future. Short circuit and thermal overload protection are provided for all motor circuits.

List of Principal Equipment Installed at Dresden Plant

2—Foster Wheeler 3 drum Stirling boilers, each 8760 sq. ft. heating surface, designed for 725 lb. per sq. in. working pressure with convection type superheaters to superheat the steam to 825° F. total temperature.
2—Foster Wheeler economizers each of 2304 sq. ft. heating surface.
2—Foster Wheeler tubular air preheaters each of 10,560 sq. ft. heating surface.
2—Sturtevant No. 1002 DWD1 induced draft fans, louvre outlet dampers.
2—Sturtevant No. 80 DWD1 forced draft fans with inlet screens.
2—Buell dust eliminators.
2—Foster Wheeler, Harding Type, D-2 unit pulverizers with classifiers at both ends supplied with fuel from Foster Wheeler feeders and connected to the fuel burners through 2—No. 26 paddle wheel exhauster fans.
4—20 in. pulverized fuel burners of the intervane type. Two burners per boiler. For starting Hauck extended nozzle oil burners are inserted.
Furnace—Water cooled furnace walls are provided of 2719 sq. ft. heating surface per boiler. Water walls and boiler tubes are nitroloy tubes. The tubes forming the bottom and part of the side walls are of wing back construction, the rest bare tubes.
2—Pennsylvania Pump & Compressor Company six stage horizontally split boiler feed pumps each for 500 g.p.m., 2040 ft. head driven by Terry type C.S. 400 hp., turbines operating at 650 lb. gage, 825 deg. F. 2 lb. g.B.P. 3500 r.p.m.
1—Goulds 3½ by 10 in. horizontal Duplex piston type motor driven pump, 90 g.p.m. 750 lb. pressure for starting up boiler feed.
1—General Electric tandem compound double flow 20,000 kw. turbine for operation with steam of 650 lb. g., 825 deg. F. at the throttle and direct coupled to generator of 20,000 kw., 25,000 kv-a., 13,200 v., 3,000 r.p.m A 100 kw. 250 v. direct coupled exciter and a 4 kw. 250 v. pilot exciter are provided.
1—Surface generator air cooler of 3680 sq. ft.
1—Westinghouse 2 pass. 16,850 sq. ft. condenser, with 2 reversible flow elbow valves, 2 vertical motor driven propeller type circulating water pumps of 10,025 g.p.m. capacity each, two, 440 g.p.m. condensate pumps, and steam air ejectors.
1—Elliott 210,000 lb. per hr. deaerating heater with 5000 gal. storage capacity.
1—Foster Wheeler low pressure heater 470 sq. ft. tube surface.
2—Foster Wheeler high pressure heaters each of 459 sq. ft. tube surface.
1—Foster Wheeler evaporator of 134 sq. ft. coil surface.
1—Foster Wheeler evaporator condenser of 202 sq. ft. tube surface.
1—Boiler feed storage tank of 15,000 gal. capacity with mounted Foster Wheeler jet condenser head for condensing superheater blowdown when starting boiler.
Coal handling and coal storage equipment—Link Belt Co.
Hydrojet ash handling system—Allen Sherman Hoff Co.
Filters and Softeners for Water Treatment—Permutit Co.
Combustion Control—General Regulator Corp.
Recorders and Meters—Bailey Meter Co.

The 230/115 v. station service board is a totally enclosed, steel switchboard with De-ion circuit breakers for feeding the power and lighting distribution cabinets. De-ion circuit breakers are also used in all distribution cabinets for branch circuit protection.

Two 125-v. batteries are used for the control circuits and emergency lighting. One is located in the station and the other in a control house at the 110 kv. switching structure. The charging and d.c. distribution panels are of the totally enclosed dead-front type.

Switchboards and Panels

A control desk for the control of the generator, power and station service transformers, and two vertical panels for the control of the outgoing lines are located in the main control room. The panels are of the all-steel, totally enclosed type with the control switches and indicating instruments mounted on the front panels, relays, watthour meters and test blocks on the rear panels.

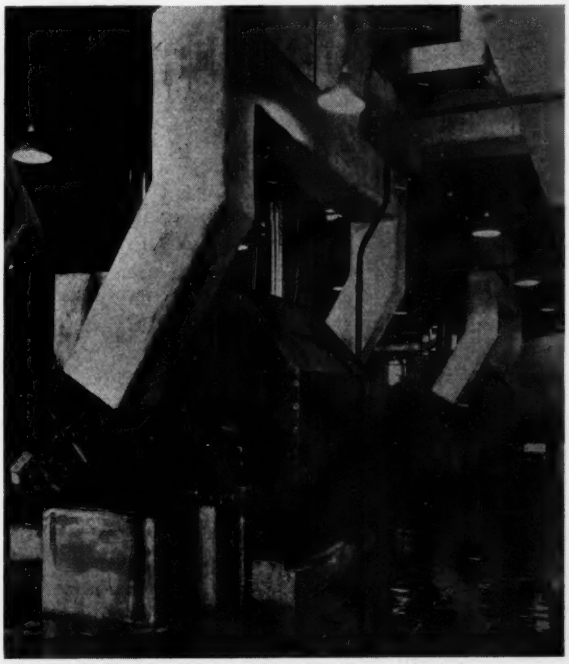


Fig. 7. This picture taken on the lower level shows two ball mills of the double classifier type with sound proof housings

Two steel panels for mounting the relays for the 114 kv. outgoing lines are located in the control house at the 114 kv. switching structure. The boiler board is located in the firing aisle between the two boilers. It consists of two boiler panels, one for each of the boilers and one master panel for the automatic boiler control equipment.

All auxiliaries essential for operating the boilers are controlled from the board and are electrically interlocked, so starting and stopping of equipment in proper sequence will be assured.

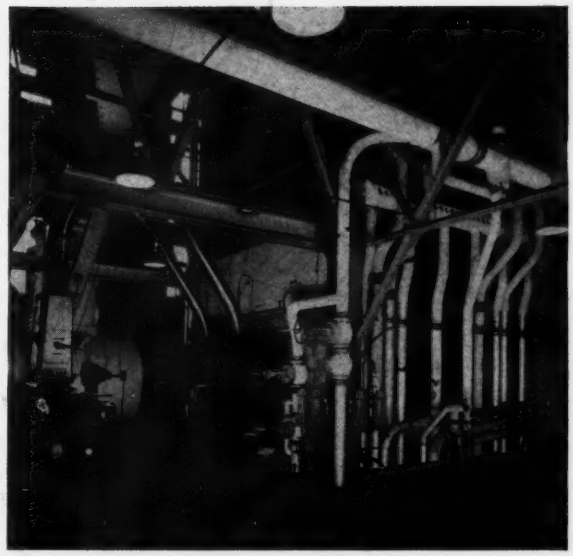


Fig. 8. The operating floor at Dresden showing the two burners and their lighting torches. At the left is the exhauster equipment drawing pulverized fuel from the ball mills on the floor below. Grouped at the corner of the furnaces are four General regulators. Note the water wall piping, the insulation of which is all metal covered

Coal handling controls are also electrically interlocked.

Work was started on the plant in April, 1937, and the unit was put in operation on March 3, 1938, and has been in regular service at full load since the beginning of April with loads up to 25,000 kw. at unity power factor.

No serious difficulties have been encountered, although thorough guarantee tests have not as yet been made, the performance seems to be up to the expectations, and it is anticipated that the plant will operate continuously at around 20,000 kw. load with a net coal consumption of approximately 0.9 lb. of coal per kw-hr.

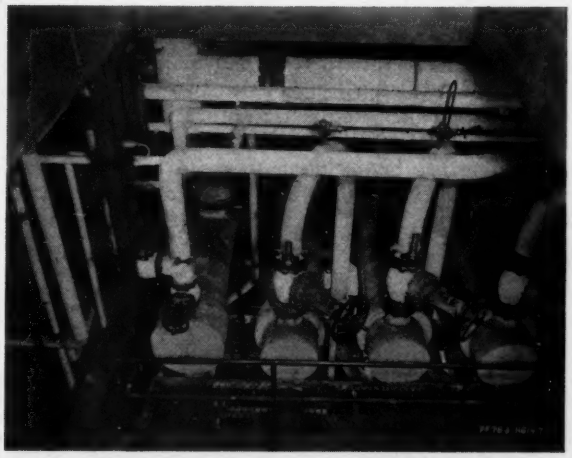


Fig. 9. This photograph shows four, shell and tube units, one of which is a single effect evaporator, a second a 202 sq. ft. evaporator condenser, a third a low pressure feedwater heater of 470 sq. ft. and the fourth a 459 sq. ft. high pressure feedwater heater

Compressed Liquid in Power Plant Cycle

More reliable steam tables have increased the accuracy of heat cycle calculations to the point where the energy imparted to the water by the feed pump must be considered. Calculations show that a 1400 lb., 400 deg. F., now common operating conditions, neglect of the compressed liquid effect results in errors of from 0.7 to 1.2 per cent.

By GEORGE G. GUTHRIE

AS THE USE of higher pressure steam becomes more and more commonplace, it may be interesting to examine the significance of compressed or unsaturated water in the power-plant cycle. The increasing amount of energy put into the boiler feedwater by pumps may make the consideration of such energy desirable in an accurate determination of the performance of bleeder turbines, feedwater heaters, and boilers. Whether or not the increment of energy present in the compressed water is of sufficient magnitude to be considered in any practical case can be decided more easily by acquiring a clear understanding of the part played by such compressed water in the power-plant picture.

What is meant by the term "compressed liquid" can be portrayed by the use of a temperature-entropy diagram. Figure 1 shows an exaggerated picture of a portion of the liquid region lying to the left of the saturated-liquid line. Points b and c represent saturated states of the liquid at two different pressures and corresponding saturation temperatures. Point a represents an unsaturated state at the same temperature as b but at a higher pressure and therefore below its saturation temperature. That is, the liquid having a pressure, as at a, must have its temperature increased further before arriving at the saturation temperature where evaporation begins. Point c on the saturated-liquid line has been chosen so as to have the same entropy as a and under this condition will be at a lower pressure, temperature, and entropy than b for

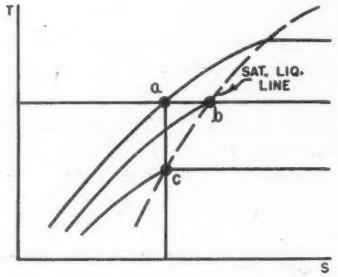


Fig. 1. Exaggerated temperature-entropy diagram of a compressed liquid state

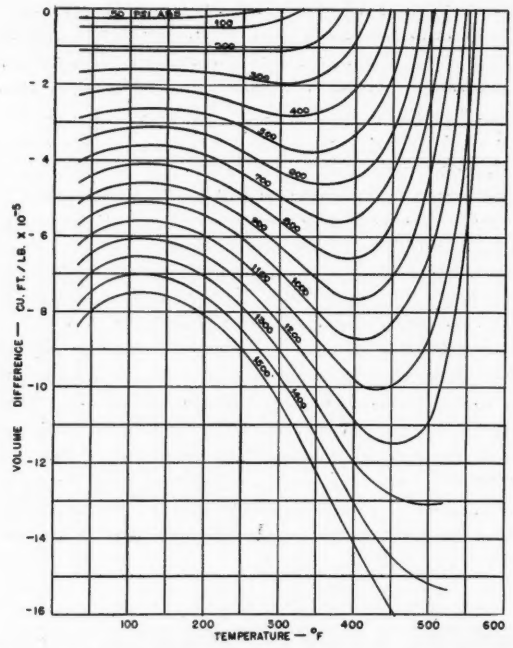


Fig. 2. Difference in volume of compressed and saturated liquid at the same temperature

all temperatures except down near 32 deg. F. Because of the compressibility of water, even though slight, the specific volume at a is always less than at b regardless of temperature. The enthalpy (or heat content) at a is greater than at c for all temperatures, and, is also greater than at b below 480 deg. F., but for higher temperatures and with pressures above 700 lb. per sq. in. abs. the enthalpy at a actually becomes less than at b. The foregoing generalizations should be confined to temperatures and pressures below the critical point of steam, 705.4 deg. F. and 3206.2 lb. per sq. in. abs., for in this range steam may actually be thought of as having a distinctly liquid phase. For a more comprehensive discussion of this compressed-liquid phenomenon the reader is referred to Keenan.[1]

Engineers are fortunate in that Keenan and Keyes[2] latest published properties of steam contain data on compressed liquids. Values of volume (v), entropy (s), and enthalpy (h) for points such as b and c on the saturated-liquid line of Fig. 1 can be taken directly from Keenan and Keyes Table 1. Values for unsaturated states such as a cannot be obtained so directly and the use of Keenan and Keyes Table 4 or their Fig. 3 is necessary.

Use of Data

This Table 4 gives the differences in volume (v), entropy (s), and enthalpy (h) between an unsaturated state of compressed liquid at a given pressure and temperature and the saturated state at the same temperature. Referring to Fig. 1 of this article, v_b, the volume at b can be found directly from Keenan and Keyes Table 1, but v_a the volume at a must be de-

[1]Thermal Properties of Compressed Liquid Water, Mechanical Engineering, February 1931, page 127.
[2]Thermodynamic Properties of Steam, by Keenan and Keyes, 1936, John Wiley & Sons, Inc.

termined by adding to v_b the value of v_a—v_b taken from Keenan and Keyes Table 4. In a similar manner s_a and h_a, the entropy and enthalpy respectively at a are obtainable by adding the values of s_a—s_b and h_a—h_b from (K. & K.) Table 4 to the values of s_b and h_b taken from (K. & K.) Table 1. As generalized earlier, the volume at a is always less than at b so that the added increment between the two is always negative, whereas, the increment of entropy is generally negative, and, the increment of enthalpy is either positive or negative depending upon the temperature and pressure. Because of the large temperature and pressure steps in Keenan and Keyes Table 4, interpolation is troublesome, so for convenience in power plant work these data have been plotted against temperature in Figs, 2, 3, and 4 of this article.

While passing, mention should be made that the chart in Keenan and Keyes Fig. 3 gives the difference in enthalpy between an unsaturated state at any given pressure and temperature and the saturated state at the same entropy. In other words, this chart expresses the values of h_a—h_c for states a and c shown in Fig. 1 of this article. Although this chart is useful in considering the performance of an ideal feed pump, which compresses water by an isentropic, or, constant entropy, process, the enthalpy and other properties of an unsaturated state are obtained more satisfactorily by the use of (K. & K.) Table 4 or the plotted values in Figs. 2, 3 and 4 herewith.

General Equation

Before creating a picture of what occurs in the feedwater circuit of an actual power-plant cycle, it

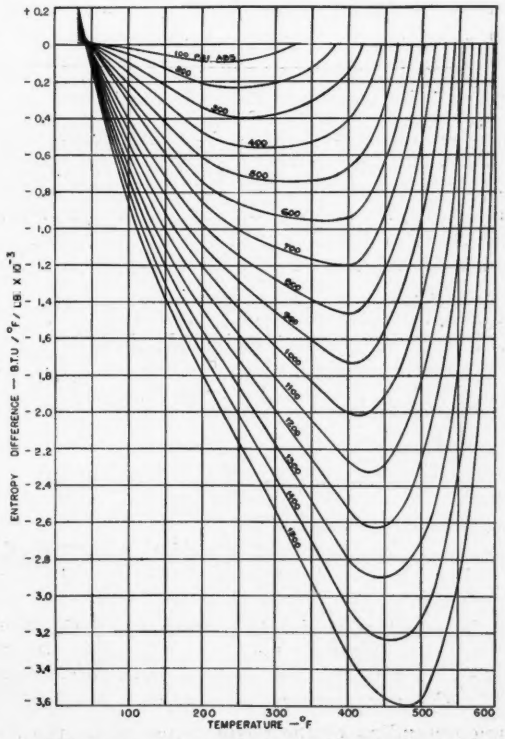


Fig. 3. Difference in entropy of compressed and saturated liquid at the same temperature

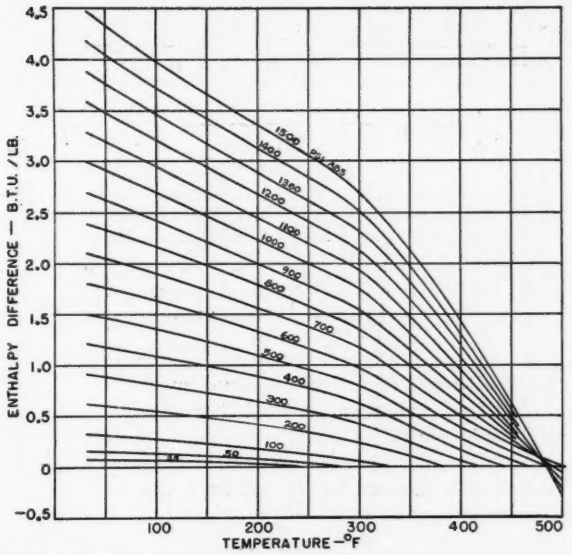


Fig. 4. Difference in enthalpy of compressed and saturated liquid at the same temperature

may be of interest to review the application of the steady-flow equation which is involved in the performance of all equipment whether pumps or heaters.[3] Figure 5 shows a universal diagram applicable to any apparatus through which a fluid is flowing at a steady rate to give or receive heat or mechanical energy. In the case of a feedwater heater or a boiler whose function is to absorb heat the total amount of energy leaving the apparatus must equal the sum of the total energy entering and the heat added to the fluid while passing through the apparatus, less any heat lost by leakage. With no difference of elevation between the measuring Points 1 and 2, with velocities V_1 and V_2 nearly equal, or, of low value, and, with no heat leakage, the complete expression of Fig. 5 can be simplified, to give, Q, the heat added, as

$$Q = w\,(h_2 - h_1). \qquad \text{Eq. 1}$$

Similarly in the case of a pump, the mechanical energy, W, received by the fluid reduces to the form

$$W = w\,(h_2 - h_1). \qquad \text{Eq. 2}$$

In practical application, in a feedwater circuit, h_1 and h_2 are determined from measurements of the pressure and temperature entering and leaving the apparatus and generally will be found in the compressed-liquid region. It is unnecessary to know anything about the process taking place within the apparatus, merely to determine the value of h_1 and h_2. Only in an ideal feed pump, in which no hydraulic friction exists, will h_1 and h_2 have the same entropy.

Application to a Power-Plant Cycle

A hypothetical feedwater circuit will now be investigated. Figure 6 show a simplified diagram of a power-plant cycle having two feedwater heaters, a hotwell pump, and a boiler feed pump. For convenience in portraying the state points numbered on Fig. 6 and on the temperature-entropy diagram, Fig. 7,

[3]For a more complete discussion see "Elements of Heat-Power Engineering" by Barnard, Ellenwood and Hirshfeld, Part I, Third Edition, p. 43, John Wiley & Sons, Inc.

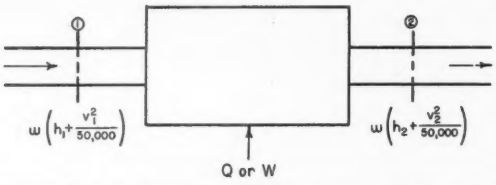


Fig. 5. Steady flow diagram for a heater or pump. In this equation, (and in Eqs. 1 and 2 of the text); Q is the heat added to the fluid in B.t.u. per hr.; W is the mechanical energy received by the fluid in B.t.u. per hr.; w is the weight of fluid flowing in lb. per hr.; h_1 and h_2 are the enthalpies of the fluid at Points 1 and 2, respectively, in B.t.u. per lb.; and V_1 and V_2 are the velocities of the fluid at Points 1 and 2, respectively, in ft. per sec.

it is assumed that the same quantity of water is flowing in all parts of the feedwater circuit.

In Fig. 7, water enters the hotwell pump at state 1, slightly below the saturation temperature corresponding to the pressure at 1, and is compressed by some undefinable process to state 2 at a higher pressure. The entropy at state 2 and the slight temperature rise from state 1 in an actual pump would be greater than if isentropic compression had occurred in an ideal pump. The ratio of the isentropic increase in enthalpy from state 1 between the same pressures and the actual h_2—h_1 would be the hydraulic efficiency of the pump if there were no heat loss from the pump.

Leaving state 2, the water flows through Heater I to state 3, at a higher temperature but at a somewhat lower pressure because of friction in the piping and the heater. From state 3 the water is compressed in a boiler-feed pump to state 4 at a higher pressure attended by a small increase in temperature and entropy. Finally, the temperature of the water is increased in flowing through Heater II until state 5 is reached. The condition of the water near the entrance to the boiler or economizer, state 6, would be at a lower pressure than at state 5 because of elevation difference and pipe friction and at a somewhat lower temperature because of heat loss.

Compressed water is of more than academic interest for some purposes in power plants operating at modern steam pressures. The decision to use the actual enthalpy of the compressed water, rather than the approximation of it obtained from Keenan and Keyes Table 1 at the given temperature, may readily be made by recourse to the magnitude of the difference involved shown in Fig. 4.

First, consider a bleeder heater used for heating 1400 lb. feedwater from 320 to 400 deg. F. If the compressed-liquid effect is neglected the enthalpy at entrance and exit from Table 1 of Keenan and Keyes would be taken at 290.28 and 374.97 B.t.u. per lb. respectively, giving an enthalpy rise of 84.69 B.t.u.

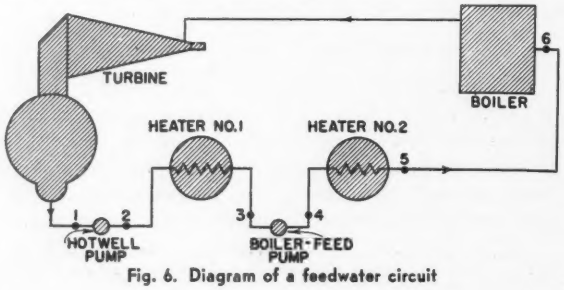


Fig. 6. Diagram of a feedwater circuit

per lb. To take into account the compressed-liquid effect, Fig. 4 shows that 2.32 B.t.u. should be added to the 290.28 B.t.u. saturated enthalpy at 320 deg. F, and that 1.31 B.t.u. should be added to the 374.97 B.t.u. enthalpy at 400 deg. F. The actual compressed-liquid enthalpies would then be 292.60 and 376.28 B.t.u. respectively or an enthalpy rise of 83.68 B.t.u. per lb. Neglecting the compressed-liquid effect results in an error of 1.01 B.t.u. or 1.2 per cent.

Next, let us consider a turbogenerator operating on a relatively high pressure regenerative cycle. In a carefully conducted heat-rate test of the turbogenerator as a unit with its feedwater heaters, the true compressed-liquid enthalpy of the feedwater leaving the final heater as well as the energy supplied to the feedwater by the several pumps in the feedwater cir-

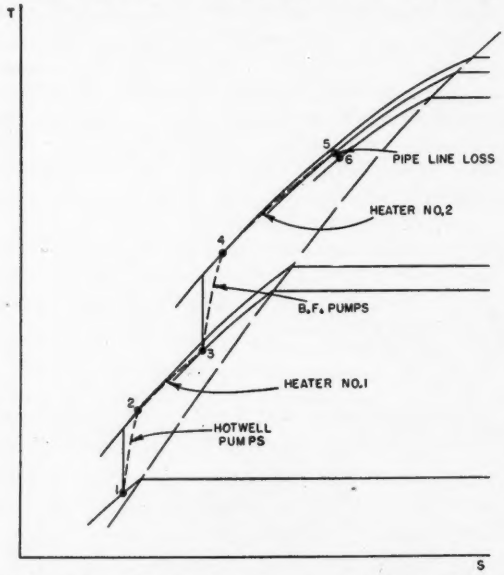


Fig. 7. Temperature-entropy diagram of a feedwater circuit

cuit should all be considered. To neglect these refinements can amount to an error as large as 0.7 per cent. It should be mentioned, however, that under circumstances justifying full consideration of the compressed-liquid effect it would only be consistent to take into account the velocities in the steam-supply and feedwater pipes.

Finally, in measuring the performance of a boiler unit, it may be desirable to include the compressed-liquid effect upon the enthalpy of the feedwater. In this application, however, the error from neglecting it would probably not exceed 0.2 per cent, and if the steam velocity in the pipe where temperature and pressure measurements are made is high enough, consideration of the velocities may completely offset the effect of compressed-liquid.

In conclusion, it should be said that no sweeping generalizations covering the use of the thermal properties of compressed liquid are possible. Figure 4 shows that the effect at moderate pressures and the lower temperatures can be as large or larger than at high pressures and the higher temperatures. Since each case must be decided for its own particular application, an understanding of the phenomenon offers the only solution.

Steam Generation from Gas Engine Exhaust

Nothing is of more vital interest to the industrial engineer than increasing the efficiency of the power cycle by the utilization of waste heat. At the annual convention of the A. I. & S. E. in Chicago, Mr. Lewis created somewhat of a sensation when he told how 20 yr. old gas engines had been equipped with water tube waste heat boilers to give a combined efficiency higher than that possible with modern steam plants. At present the trend in steel plants seems to be toward the utilization of blast furnace gas under boilers but Mr. Lewis' paper, presented here in brief, will undoubtedly have a considerable bearing on future practice.

By T. A. LEWIS

Combustion Engineer
Bethlehem Steel Co.
Bethlehem, Pa.

EVER SINCE heavy-duty gas engines found successful application as prime movers in the steel industry, no little amount of effort has been expended in developing a type of waste heat boiler for the efficient utilization of sensible heat in the exhaust gases. So far as it is known, the first designs of waste heat boilers for this purpose in the United States were made in 1918. By 1935, the design had developed to such a point that the unit was reliable and, coincidentally, gas engine performance had been improved to such an extent that the application was warranted.

Before the year was over, Bethlehem Steel Company had equipped one of its gas engines at the Bethlehem, Pa., plant with a waste-heat boiler unit of the type shown by Fig. 1 which, except for slight delays in engine operations, has been in continuous service. So successful was this installation that seven more units followed. These waste-heat boilers, equipped with economizers, are the first units of their kind to be used in this country to recover waste heat from the exhaust of large gas engines and utilize it efficiently in generating more steam for the steel plant.

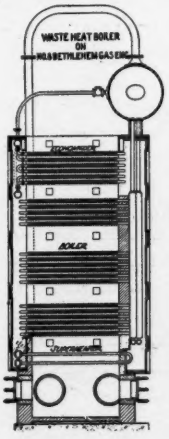


Fig. 1. Type of waste heat boiler on No. 8 Bethlehem gas engine which has been in continuous operation for over 2 yr. Under the temperature gradients shown by Fig. 3 the superheater accounts for 9.2 per cent of the total heat absorption; the first bank of tubes, 46.4 per cent; the second bank, 21.9 per cent; the third bank, 11.6 per cent; and the economizer, 10.9 per cent

Despite the fact that the trend in mill drives is toward complete electrification, normal steel plant operations still require a large supply of steam. This and all other heat requirements, shown by means of the fuel distribution flow sheet, Fig. 2, involve a large quantity of purchased heat in the form of electric power, oil and coal. By referring to this chart, it will

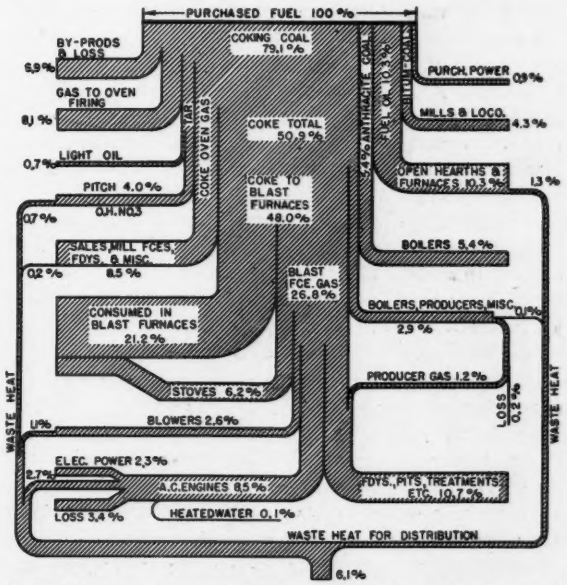


Fig. 2. Heat flow sheet of the Bethlehem Plant of the Bethlehem Steel Co. showing the percentage of waste heat distribution as compared with the total plant requirements

be seen that waste heat distribution represents 6.1 per cent of the total, an amount that influenced the application of waste heat boilers on these gas engines at the Bethlehem plant.

Due to the low calorific value of blast furnace gas, steel plants have been slow to utilize it for other than stove and boiler purposes. A 500-ton furnace will supply about 2,000,000 cu. ft. of gas per hr. above its own requirements. The steam load in steel plants with power units is very high, and the natural procedure is, therefore, to use this gas for boiler purposes. However, with increasing fuel prices the tendency is to use blast furnace gas in gas engines and metallurgical

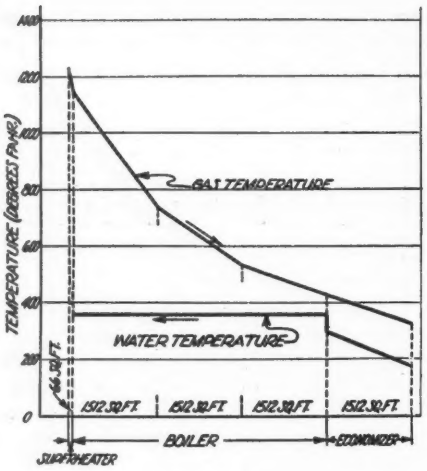
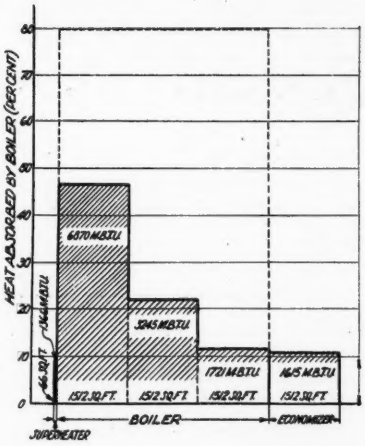


Fig. 3. Temperature gradients through No. 8 gas engine waste heat boiler. Steam generation is at 165 to 200 lb., 200 deg. F. superheat. At an average engine output of 3480 kw., the steam generation is 3.45 lb. per kw-hr.

Right: Heat absorbed through surfaces of No. 8 engine waste heat boiler



furnaces before using it under boilers. Waste heat boilers should be applied to all large gas engines and to metallurgical furnaces if the return warrants the installation.

Boiler Performance

The amount of steam which can be generated in a waste heat boiler when supplied with a definite quantity of gas at a given temperature depends on the size of the boiler and the allowable draft loss. In practice, the theoretical limit of recovery is the heat in the gases between the temperature at which they leave the engine and the temperature of saturated steam at the desired operating pressure, or the temperature of the feedwater if economizers are provided. It is not practicable, however, to build a boiler that even closely approaches this condition, but it is economically feasible to design a boiler with an efficiency up to 70 per cent if it is permissible to build up a draft loss of about 4 in. of water or higher through the boiler.

Much progress in power plant economy has been made during the past 10 yr. This has principally been accomplished by resorting to various combinations of regenerative feedwater heating, steam reheating and extraction of heat from the flue gas by means of economizers and air preheaters. All these highly improved power schemes are excellent, but with their complications the simpler gas engine and waste heat boiler combination is more advantageous with a load of the type found in the steel industry.

The present gas engine waste heat boiler unit has demonstrated clearly what operating results are attainable. For further improvements it will be necessary to go to larger units. As far as advantages are concerned, units of twice the present size are comparable with larger turbine units. Such a unit should be able to generate on the shaft the equivalent of 8000 kw., with an additional 2600 kw. from waste heat boiler steam, and is well adapted to a steel plant with an electric load of 20,000 kw. or more. For a smaller power load the present units are ample.

In Europe there are gas engine units generating in excess of 7000 kw. and gas engine blowers delivering 135,000 cu. ft. of 15.6 lb. air per minute. Size for size these are more efficient than the present size units, because mechanical losses and losses through jacket water and radiation are smaller.

Summary

Summarizing, in steel plant operation, the Bethlehem gas engine that has been in operation for the past 20 yr., but complete renovated, has been able to compete with the modern turbine units. Furthermore, application of waste heat boilers has reduced operating cost to the extent where such a combination is the only logical one. As the size of the gas engine increases, the advantage becomes still greater. Compared with a turbine station, the gas engine-waste heat boiler system requires only half the amount of fuel, for the same power output, releasing the remaining half for metallurgical furnaces. Normally, this advantage is still further enhanced due to the fact that a higher priced fuel is used for metallurgical furnaces.

The final analysis of any scheme is the ultimate cost to the producer. The combination gas engine and waste heat boiler can meet the initial cost of installation and give a lower operating cost. Due to the higher thermal efficiency of this combination, its advantage becomes greater with increasing price of fuel.

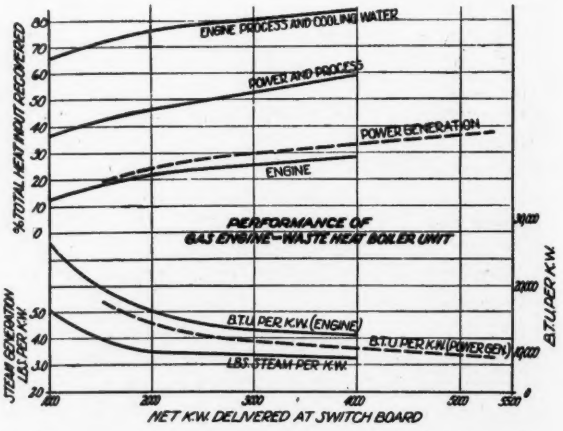


Fig. 4. Performance of the gas engine-waste heat boiler unit

Supercharging Diesel Engines[1]

Supercharging advantages on some types of engines and for some services where space and weight limitations exist. Output may be increased 50 per cent

By HARTE COOKE
American Locomotive Co.

SUPERCHARGING of Diesel engines is primarily intended to increase the output of an engine of given dimensions. It first came into use to supply air to an engine which operated at considerable altitude so that it would be able to develop its full output at the elevated location. It seemed that if the output at altitude could be increased to the normal sea level output, and, unless some unforseen difficulty appeared, it would be possible to increase the sea level output. This would be advantageous in many cases for the saving in space required for a given power and also in other cases for the saving in weight for a given output.

In general, the output of a Diesel engine is limited in larger sizes by the heat conditions that parts of the combustion chamber can stand. For the smaller sizes, however, on account of the high ratio of cooling surface to the volume of the combustion chamber, the output is limited by the mean effective pressure that can be developed.

Temperatures

The maximum temperature depends on the ratio of the fuel burned to the air present in the cylinder, the air performing two functions, one function to furnish the oxygen for combustion and the other to act as a diluent to limit the maximum temperature. This means that with a given engine, if the mean effective pressure is increased beyond a certain limit, the maximum temperature will increase proportionately and the heat transfer being as the fourth power of the temperature difference, will cause excessive maintenance. In view of the above, it can be seen that if more air is provided in the cylinder by introducing it at a pressure above atmospheric pressure, more fuel can be burned without increasing the maximum temperature because the ratio of air and fuel will be the same.

Supplying the air at a pressure above the pressure of the atmosphere, increases the amount of air present in the cylinder during combustion more than is at first apparent. Say, with 5 lb. ga. pressure, it would seem that 1/3 more air would be present in the cylinder, and consequently 1/3 more fuel could be burned. However, there are a number of other things to consider than just the pressure in the manifold. In the first place, due to the overlap of the valves the small normal scavenging which takes place ordinarily in a Diesel engine is very much increased when supercharged. In fact, the overlap is generally purposely increased to increase this scavenging effect.

This means first, that the hot gases in the clearance space amounting to about 7 per cent of the total are expelled by the incoming air. Also a portion of this intake air blows over the hot piston and through the exhaust valve giving a considerable cooling so that the air charge is drawn into the cylinder, is at a much lower temperature than it would be normally, so that instead of 1/3 more air in the cylinder, there is probably in the neighborhood of 50 per cent or more weight of air than there is in the normal un-supercharged engine. This means that in the neighborhood of 50 per cent more fuel can be burned with no higher maximum temperature than before.

Maximum Pressure

The pressure at the end of compression in the engine will be increased about in proportion to the absolute pressure of the air in the intake manifold. This does not mean, however, that the maximum pressure in the cylinder will be materially increased, the reason being that at the higher pressure at which the combustion takes place, the combustion is more prompt and more complete, and this is due in part to the fact that the ignition temperature of the fuel is lower at the higher pressure, while the temperature in the cylinder is about the same as with the normal engine, due to the reduced ignition temperature of the fuel at this higher pressure, combustion is more prompt and complete. Therefore, the rise in pressure from the compression pressure to the maximum pressure is less with a supercharged engine, so that the maximum pressure is not materially increased.

We have found that with 5 lb. supercharging pressure, with practically the normal compression ratio, that the maximum pressure is practically the same as with the un-supercharged engine. With the smaller engines, the cooling effect of supercharging, which reduces the maximum temperature, is not so important as the improvement in the combustion due to the higher density.

It should be remembered that the temperature at the top of compression is a function of the volume ratio and not the pressure. Therefore, to get the temperature desired for ignition, the compression ratio cannot be reduced beyond the point where proper ignition is obtained. For this reason with large engines, due to the lower cooling ratio of the cylinder walls, the necessary temperature for ignition could be obtained with a lower compression ratio, than with small engines. Therefore, in all probability, more increase in output could be obtained with the large engines than with small engines, provided the limita-

[1]From a paper presented at the annual meeting of the Society of Automotive Engineers at Detroit, Mich., January 1938.

tion on the supercharging was the maximum pressure in the cylinder.

Air-Supply

To provide the air for supercharging, various arrangements have been used. A reciprocating pump can be used the same as is used for the scavenging air of the two cycle engines. The most outstanding example of the use of a reciprocating pump for supercharging was on the Werkspoor engines. A great many of the Werkspoor marine engines are supercharged in this way. An increase in output of about 50 per cent is obtained with about 5 lb. supercharging pressure and the increase in cost and weight is a very small amount and there is no increase in space required.

Another arrangement is the application of a displacement blower for the purpose of supercharging, as developed by Burmeister & Wain, who use a Roots type blower at the back of the engine driven by a chain from the engine shaft.

A turbo-type blower driven by a motor has been used in a good many cases and this has some advantages for with normal arrangement the delivery of the air is steady, the only pulsations being those due to the intake of the engine cylinders. The current for driving the motor may be obtained from the unit being supercharged, or from other sources. The air can also be supplied by a turbo-type fan driven by the engine itself such as is done on practically all aircraft gasoline engines. This makes a simple and compact arrangement, but due to the difficulties with the high speed shaft and gearing, it has not yet come into use on Diesel engines.

The method of supercharging which has been used more than all others is a turbo-blower, the turbine being driven by exhaust gases from the Diesel engine such as is done by Rateau of France and Buchi of Switzerland. To facilitate the scavenging of the cylinders at low supercharging pressures, Buchi divides the exhaust pipe so that the pressure due to the exhaust of one cylinder does not interfere with the scavenging of the cylinder next to it.

This is an interesting development and while the power for driving the blower is not obtained for nothing, as the turbine puts a considerable back pressure on the engine, this back pressure is so moderate, however, that the fuel consumption of the supercharged engine is better than with the engine unsupercharged. Also, it is self-regulating because at light loads there is less heat in the exhaust and the turbine runs at lower speed and provides the supercharging air at a lower pressure which conserves power and increases the mechanical efficiency at light loads.

Is It Worth While?

In regard to which system should be used, this decision will be governed in all cases by the local conditions of the installation being considered. For instance, with a new installation, if a motor driven supercharger was considered it would probably be found that the cost of the motor driven blower, pipe connections to the engine, the extra generator capacity required in the main generator, the inter-connection of the generator to the motor, with the necessary controls, would cost more than putting additional cylinders on the main engine to develop the power. However, with an existing engine in a space which is limited and where a considerable increase in output is desired, it might be very desirable to use a motor driven blower to supercharge the engine, the power for driving the blower being taken from a separate unit. This would give a large increase in the power that could be developed in a given space and in most cases would more than justify the extra cost of this arrangement.

The Buchi type of supercharger could be added to nearly any installation. About the only changes necessary in the main engine would be such changes in the cam shaft as is necessary to give the proper overlap to the intake and exhaust valves, and such change in the fuel pumps and fuel valves as is necessary to deliver the extra fuel. With new installations, it is just a question of whether the installation of the Buchi supercharging equipment would cost more than providing extra cylinders to give the increased output.

On small and moderate size marine engines, one of the forms of supercharging would usually be found to be advantageous, as it would reduce space and weight even if there was no saving in first cost. For the larger marine engines, where two cycle engines are almost universally used, little or no supercharging can be obtained as the time period for introducing the extra air required is too short.

For locomotives and railway equipment, supercharging of four cycle engines is very advantageous as a very considerable increase in output can be obtained with little increase in weight or space. The method used would depend on the local conditions and the extra cost is more than justified by the results obtained.

With high speed, two cycle equipment, practically no supercharging can be obtained on account of the short time period available for getting the air into the cylinder. An arrangement of a gas turbine driven blower, however, in series with the regular scavening blower has been used to increase the mechanical efficiency of the engine, which is beneficial, but the saving possible, hardly justifies the extra equipment required.

For stationary engines, any of the types of superchargers may be used, the simplest one for the conditions or the one with the least investment should be selected, otherwise it may be cheaper to put more cylinders on the engine and not use a supercharger.

The general economies of supercharging work out best if considerable supercharging is used as this requires only a small extra cost of the supercharging equipment and gives much more return in output from the engine.

The essential characteristics of supercharging equipment is the same for small engines as for large engines, only of smaller size so for small engines the cost of the supercharging equipment would probably be relatively greater and the economics of its use would be controlled by a possible saving in weight and space.

For larger, four cycle engines, however, supercharging would seem to be very desirable as indicated by the economics of various installations. The

possible limits of the increase in output for a Diesel engine are not yet known but this limit will probably vary with each particular case. The reason why supercharging has not been in more common use is that the cost of supercharging equipment up-to-date has usually been so much that it seems better to supply the extra power by adding more cylinders or more units.

Operation

In regard to the actual operation of the supercharged units, supercharging from all the background that has now been accumulated, seems to have a beneficial effect on the engine itself and the exhaust valves require less attention, the wear of the engine is reduced, and the engine in general seems to work better supercharged than unsupercharged.

With the supercharging equipment itself, however, a sufficient background of experience has not yet been obtained so that the best operation can be expected. With turbo-type superchargers, the air impellers at times become coated with a deposit which is apparently caused by a small amount of oil in the air which sticks to the impeller and catches the dust which passes through, so this deposit may build up to perhaps one-half the opening of the air passages which causes a very considerable reduction in the capacity of the blower so that the supercharging pressure may be even cut in half. This trouble, however, can be easily taken care of when once the trouble is discovered. The blower can be run with an open delivery and Oakite Plater's Cleaner can be fed in with the air for a few minutes, and the coating will be removed.

Go-Devil Helps Diesel

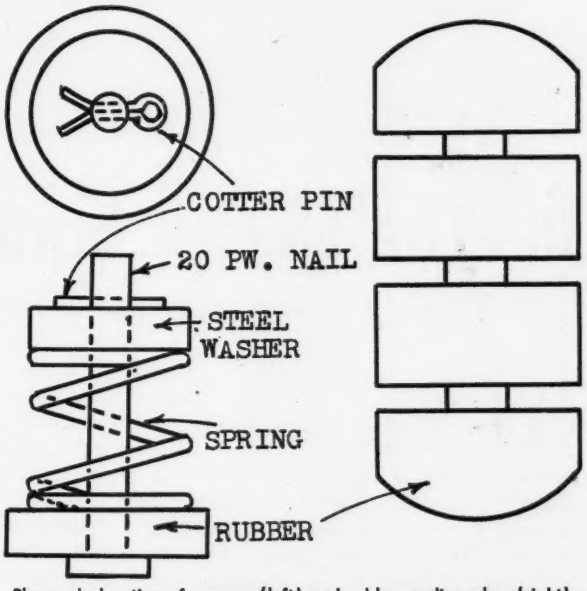
Plug scraper and compressed air cleans oil lines that could not be removed. By Charles C. Lynde

AFTER UPWARDS of 30,000 operating hours the oil leads from the built-in pump to the main bearings of a battery of 600-hp. Diesels began to give trouble by clogging. The ½-in. lines had been formed to fit within the engines at time of erection and could not be removed without extensive dismantling. Bends all on a 3 in. radius, lay close against the edges of the crankcase space, and were without joints save where they tied in to the pump manifold at one end or the bearing cap at the other. At each overhaul shutdown these lines had been blown through with compressed air, but as long as air found a way through, there was no way of determining the extent of deposits of sludge and carbon particles which eventually cut off the flow entirely.

Working a flexible wire through the leads and pulling a swab was tried, but was not successful due to the many turns, some lines having as many as six 90 deg. bends. The alternative seemed to be to cut out the original oil leads and install new ones with unions and ells so as to enable them to be removed for cleaning. The possibility of leaks led to the trial of a form of "go-devil" or scraper which was patterned (remotely) after the scraper used in crude oil lines.

The scraper itself consisted of a rubber washer mounted against the head of a 1-in. section of 20-penny nail, and having on it a spiral spring, compressed by a steel washer and held in place by a cotter through the end of the spindle. As a ½-in. pipe is actually 0.622 in. in diameter, the rubber washer was cut this size, but the steel or scraping washer and the spring was made ½-in. This permitted the steel to cut free the deposits, while the spring and rubber washer aided in carrying them forward.

Driven by a rubber plug the scraper was 0.622 in. in diameter with three deep grooves at regular intervals in its 1½ in. length. This plug, introduced into a lead behind the scraper, fitted tightly against the



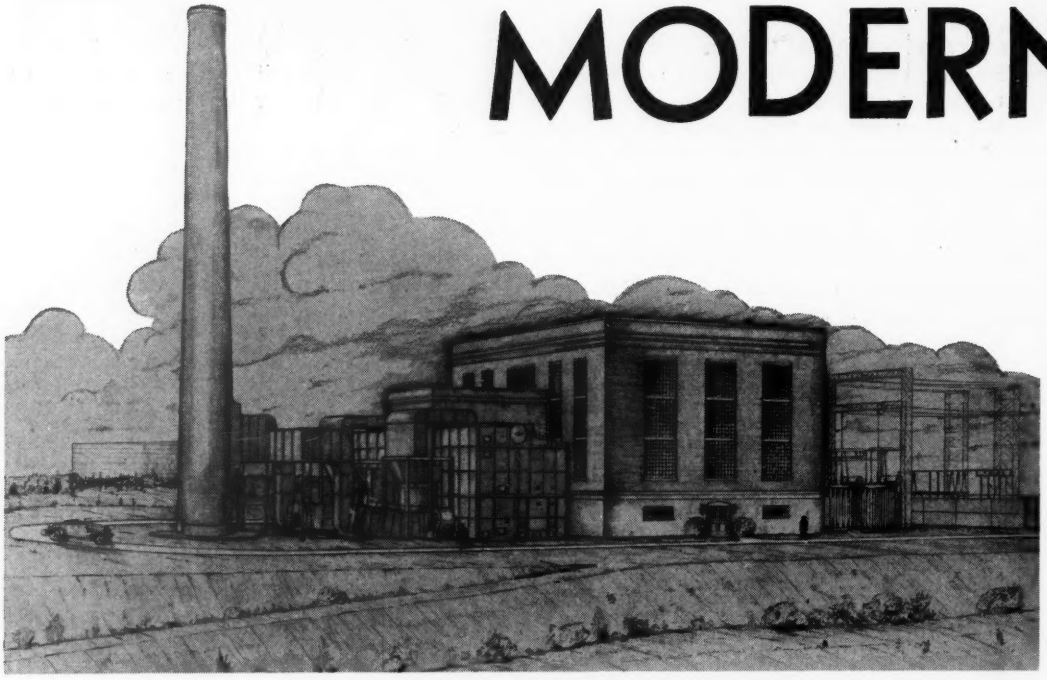
Plan and elevation of scraper (left) and rubber sealing plug (right). The illustration is about twice the actual size needed for a ½ in. line. The rubber was frozen and turned to shape in a lathe

tube walls, yet could bend around the turns without losing the tight contact of the wide portions against oil line. The assembly was blown through the oil lines with compressed air at 100 lb. pressure, emerging from the further end in a shower of sludge and carbon with the speed and hitting power of a shotgun wad.

The rubber driving plug was turned on an ordinary lathe, after having been frozen to a bakelite-like hardness with dry ice, a material which it greatly resembled under the turning tool. When again at room temperatures, the rubber regained its elasticity and served admirably as a seal between the scraper and impelling air.

Since the first application of the "go-devil", when the lines were known to be in bad order, the device has been sent through all oil leads at each shut-down for overhaul, and the lines now always flow clear oil, at maximum capacity.

MODERN



III—The Electric Bond and Share Group

By Louis Elliott, Consulting Mechanical Engineer, Ebasco Services, Inc., New York, N. Y.

EXTENSIONS AND IMPROVEMENTS to generating facilities, as part of a comprehensive program involving heavy expenditures of new capital, was carried out by this group of utility companies in the late 1920's, and was still under way on a large scale in 1929 when the business depression began. Shortly thereafter, public officials urged the electric light and power industry, along with others, to continue its construction program to help maintain employment and provide purchasing power. The companies of this group cooperated in that effort and continued to make heavy expenditures in 1930 and 1931 to complete the construction program.

The succeeding sharp drop in their business left the companies with excess generating and other facilities so practically no new projects were undertaken until 1935. By that time, while the utilities were able to carry their loads comfortably, it appeared that, in some cases, provision should be made for additional loads and for reserves, to give adequate protection to service of existing customers. A number of companies in the group, therefore, authorized work on new plants and extensions of existing plants, both steam and hydro-electric.[2] The aggregate capacity of these new steam developments in the United States has been about 175,000 kw. Ebasco Services Incorporated, service subsidiary of Electric Bond & Share Co., has acted as consulting engineer in such developments.

This article summarizes the steam electric power work undertaken by Ebasco client companies, since 1935, and illustrates the trend in generating-station design, by describing in considerable detail one of the latest of the new plants under construction, and, by referring briefly to others.

Steam Conditions

Choice of steam conditions and selection of equipment have been determined by the economics of each situation, taking into account such factors as cost of fuel, expected capacity factor and relative investment for alternate designs. Where the economic differential was not great, selection of equipment was influenced by factors, such as availability and short shipment of certain apparatus, or, special conditions of operation, as auxiliary to a hydro-electric system. For a superposed unit, steam conditions such as 1200 lb. and 900 deg. F. would, under present conditions, be selected, most frequently, and for condensing installations, 850 lb., 900 deg. F. or 650 lb., 825 deg. F., unless the plant was expected to be operated under very low period load factor, in which case 400 lb. 750 deg. F. might be chosen.

Table I is summary of physical data for major to important equipment installed, or, to be installed at

[1]This station, consisting of a 375 lb. 700 deg. F. 15,000 kw. turbine and two 150,000 lb. per hr. boilers, was put into service by Central Arizona Light and Power Co. in May 1930. It was described briefly on pp. 13 to 20 of the October issue of Combustion.

[2]The new Upper Salmon Falls hydro-electric development of Idaho Power Co. was described on page 100 of the February 1938 issue of Power Plant Engineering. This, the sixth development of the company on Snake River, consists of two 9000-kw. generators driven by Smith-Kaplan turbines rated at 13,000 hp. under a net head of 44 ft.

UTILITY STATIONS

Operating properties of Electric Bond and Share Group in this country are widely distributed, and are divided into three major groups, subsidiary to American Power & Light Company, Electric Power & Light Corporation and National Power & Light Company. Engineering policies have been farsighted and progressive, resulting in a balanced program of steam, hydro-electric and Diesel power development, with interconnections to meet present and future economic needs of the local units. Deepwater (Texas) was one of the first high-pressure "tops", and operating experience there has lent encouragement to utilization of high-pressure high-temperature equipment in recent extensive building program in United States. Central Arizona station[1] near Phoenix was one of the first employing semi-outdoor construction, which is an outstanding feature of the Ebasco program. This type of construction is being used as far north as Utah and Nebraska and is, it is felt, capable of further development. Steam conditions selected, as economic for the various operating needs, include: 1200 lb. 900 to 950 deg. F.; 850 lb. 900 deg. F.; 650 lb. 825 deg. F.; and 400 lb. 750 deg. F.

stations described below. Although no internal-combustion engine installations are described, as part of recent power development program, there is a considerable number of Diesel units operating on properties of Ebasco client companies. Diesel plants are utilized when the character of available fuel and water supply, magnitude of development, and general conditions and economics, indicate installation of oil engines rather than steam equipment.

One important development in steam-plant design has been the adoption of a semi-outdoor type, utilizing outdoor boilers and other equipment to materially reduce investment in station building and related structures. This design is capable of further development, leading to additional economies. Mountain Creek plant of Dallas Power & Light Co. is a recent example of semi-outdoor construction.

Mountain Creek Semi-Outdoor Station

As the capacity of existing generating station sites at Dallas is extremely limited, the company some time ago made a survey to determine best location for a new development. A major problem in Texas is provision of condensing-water facilities as most of the streams are flashy, with long periods of low flow. The watershed of Mountain Creek, southwest of Dallas, was chosen as best source of water supply. A dam site was selected and dam construction started, a number of years ago, to create a cooling pond and provide ample storage of water the tide over long dry periods. Completion of dam was however postponed until 1936, because load growth was materially retarded by depression conditions, and provision of new capacity to sup-

Fig. 1. (Top of opposite page) Architect's sketch of exterior of Mountain Creek Station of Dallas Power & Light Co. The integral-furnace boiler is well adapted to the semi-outdoor construction, which has been found effective by the E. B. & S. Group in reducing station costs Fig. 2. (Right) Provo station of Utah Power & Light Co. went into service late in 1936 and was one of the first semi-outdoor plants. The height of turbine room to roof girders is only 17 ft., but roof hatches permit the 25-t. gantry crane to pick up any part of turbine. The bent-tube boiler is chain-grate-fired and lower part of furnace is water-cooled. Although boiler details differ, general setting arrangement is somewhat similar to that of the Jones St. (Omaha) boiler shown in Fig. 6

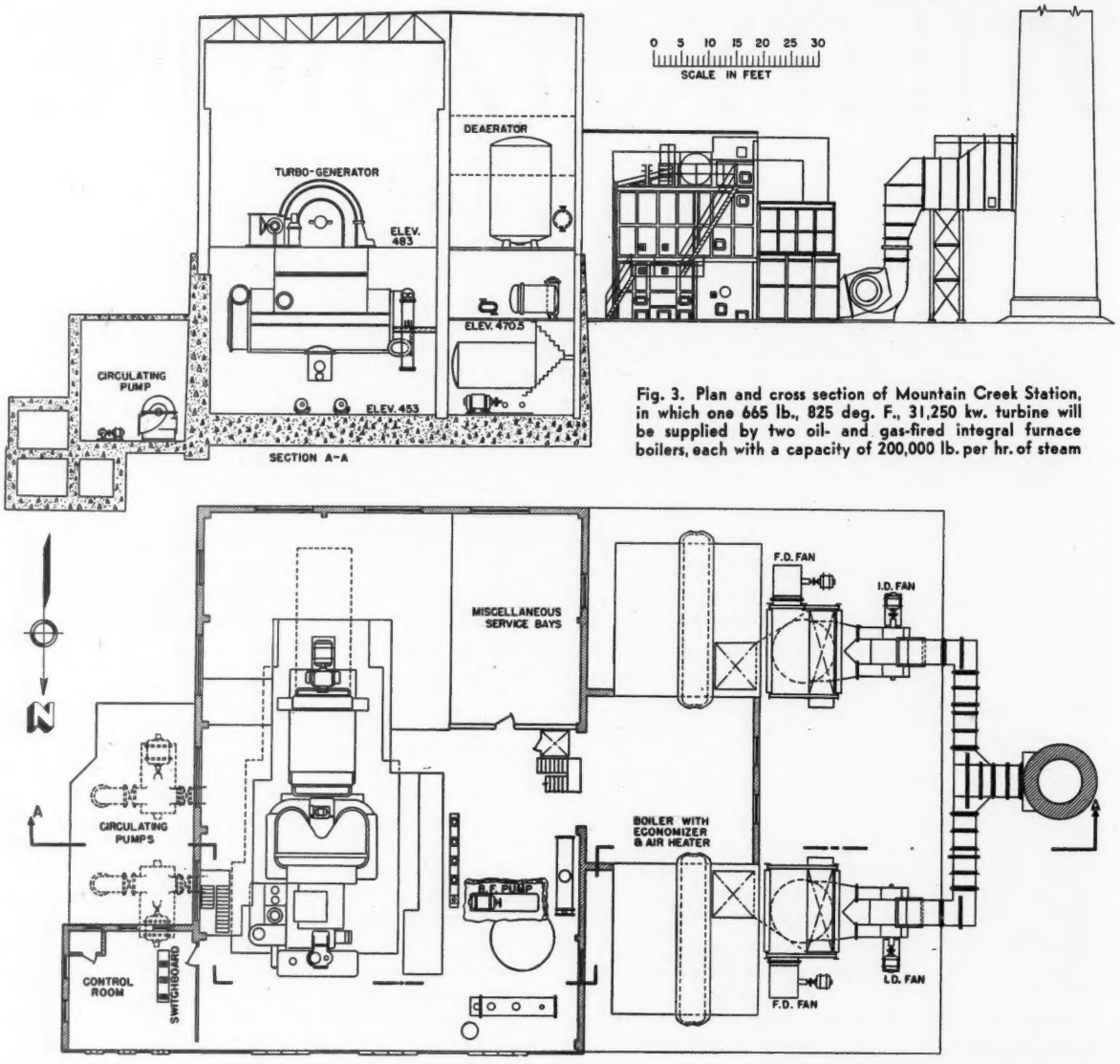


Fig. 3. Plan and cross section of Mountain Creek Station, in which one 665 lb., 825 deg. F., 31,250 kw. turbine will be supplied by two oil- and gas-fired integral furnace boilers, each with a capacity of 200,000 lb. per hr. of steam

ply firm power for the important Dallas load, could be deferred.

Mountain Creek reservoir has an area at normal high water line of between 5 and 6 sq. mi., a storage capacity of 18,500 day-second feet (1600 million cu. ft.), sufficient to maintain a condensing-water supply over the most severe drought yet recorded. This lake, in addition to serving new steam station, will constitute an important asset to Dallas from recreation and general viewpoint.

From concrete intake and screen well on the waterfront, condensing water is taken by means of a tunnel to the station, and is then discharged "upstream," behind a riprapped dike, assuring 3400 ft. distance between point of discharge into reservoir and intake.

Building Features

Figure 1 is a reproduction of architect's sketch of Mountain Creek plant, showing main building housing the turbine and auxiliary equipment, two outdoor integral-type boilers with housing for operators between them, outdoor forced-draft and induced-draft fans, with flues leading to an independent chimney, and, on the other side of the station, step-up transformers and a switchyard. The building is of relatively compact design, five bays or 95 ft. long, the span of turbine-room crane is 43 ft. and the auxiliary bay is 24 ft. wide. The structure is about 50 ft. high from grade, or approximately 70 from condenser-basement floor.

Figure 3 shows the arrangement of the major equipment in plan and elevation. The basement is largely taken up by condensing equipment, feed pumps and water treating and pumping apparatus. One portion of the auxiliary bay is devoted to feedwater equipment, and another to a number of miscellaneous plant services such as auxiliary electrical, shop, storehouse, ventilation and office. Electrical controls are grouped in a one-bay structure adjacent to the building, next to temporary end.

Boilers are placed alongside the auxiliary bay, with shelter for the operators between the two outdoor units; this operating room is of sufficient height to take in the ends of the drums to which gage glasses are connected. Practically no expense is incurred in looking forward to possible future use of solid fuel, but the arrangement is such that direct-firing pulverizing mills and raw coal bunkers may be installed when and if required.

Saves $75,000

Saving in investment resulting from use of outdoor boilers, as compared with boiler house of conventional type constructed of the same materials as the turbine room and auxiliary bay, is of the magnitude of $75,000. This saving is equivalent, in its effect on the combined fixed and production costs of energy, to a reduction of about 5 per cent in fuel consumption or cost.

Experience with older types of power-house ventilation, utilizing ventilating sash and depending largely upon currents of air induced by heat from equipment, or upon outside atmospheric conditions, has been somewhat unsatisfactory, and Mountain Creek station is designed with fixed sash and with apparatus for supplying positive ventilation. Ventilating fans are placed in a room on the top floor of the auxiliary bay, taking outdoor air through a filter, passing it over a coil through which is circulated water cooled by spraying on the roof, and discharging through ducts to various parts of building. The cooled air will be brought to within perhaps 5 deg. F. of wet bulb, or approximately 30 deg. F. below the outdoor dry bulb temperature on a hot summer day. The design by no means provides complete air conditioning, which would hardly be economic for a steam station, but should give conditions materially better than with conventional ventilation. Troubles resulting from the entrance of dust, of insects, and of rain blown in or around the windows, should also be reduced.

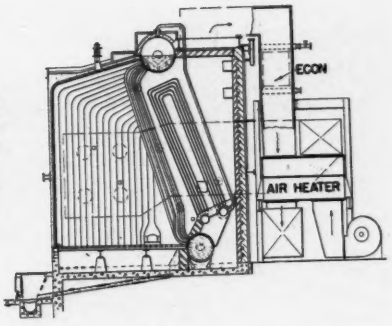


Fig. 5. Cross section of Mountain Creek boilers, designed for 750 lb. pressure, 830 deg. F. total temperature and a steam output of 200,000 lb. per hr. each

Mechanical Design

Major equipment includes one 32,250 kw. 0.87 p.f. steam turbogenerator; two integral-furnace boilers with economizers and airheaters, fired by natural gas with oil reserve; feed-heating equipment designed for three-point bleed of turbine; water-treating apparatus including zeolite softener and evaporator.

Normal steam conditions of 650 lb. and 825 deg. F. were determined by an economic study, the decision being also influenced by certain general considerations. Heat-balance computations indicate, for normal full load on turbogenerator, a heat consumption of about 13,500 B.t.u. per kw-hr. net plant output. Figure 4 is an estimated heat-flow chart for one set of conditions.

The construction program calls for operation of the plant during the spring of 1938 and as it will be the most economical generating capacity of Dallas Power & Light Co., it will run on a base load. The general design is therefore laid out for reliable high load-factor operation, although investment for spare equipment, as well as in structures, has been kept moderate.

Other important steam developments in this country, made during past 2 or 3 yr. on properties of Ebasco client companies, are briefly described below.

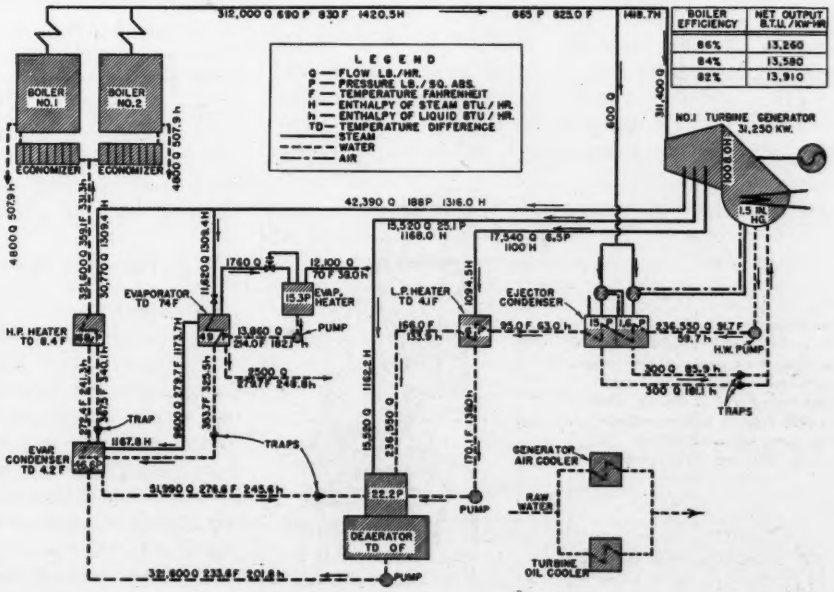


Fig. 4. Heat balance of Mountain Creek Station at 31,250 kw. load and 1.5 in. back pressure. At this load, auxiliaries will use 1300 kw., giving a net output of 29,950 kw. and a heat rate, with boiler efficiency 86 per cent, of 13,260 B.t.u. per net kw-hr.

Fig. 7. This 5000 ft. 14-in. line carries up to 200,000 lb. per hr. of 350 lb., 700 deg. F. steam from Deepwater Station of Houston Lighting & Power Co. to the new Champion Paper & Fibre Co. mill. The other pipe is a 4-in. condensate return. In the distance the line is shown crossing Vinces Bayou, on timber supports

Semi-Outdoor Station, Provo, Utah

Utah Power & Light Co., early in 1936, found that increasing load, combined with deficient water supply for the hydro-electric system, would call for additional steam capacity in the magnitude of 15,000 to 20,000 kw., to be in operation by the fall of that year.

A 15,000 kw., 400 lb. 750 deg. F. turbogenerator, available in 4 mo., was located, and quick delivery was also obtained on one boiler unit served by traveling-grate stoker. In order to expedite design and construction, and at the same time conserve investment in a plant normally serving as standby to hydro-electric system, expense for structures was minimized and the general design simplified.

As shown by Fig. 2, the boiler was placed outdoors, with an induced-draft fan and short stack on top, and with housing around its base for protection of firemen. The turbine was enclosed in a compact building, and a gantry crane provided, tramming over turbine room, for handling parts through roof hatches. Condensing-water works were of simplest character, taking water from an irrigation ditch. Switchboard and main electrical controls were located in an existing hydro-electric station about 1000 ft. distant.

Saving in investment, by utilizing simple compact semi-outdoor construction, was estimated at between $100,000 and $150,000, as compared with conventional fully housed design.

This plant was constructed between February and August of 1936, and ran under high load factor through September and following months as required to carry the system load. As an example of station economy, heat consumption for a recent month (October 1937) was approximately 15,400 b.t.u. per kw-hr. net output. Only minor difficulties resulting from semi-outdoor design have been experienced. A brief description of the plant was given in the Electrical World, July 4, 1936.

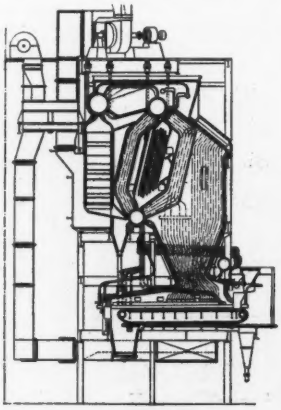


Fig. 6. At Jones St. Station of Nebraska Power Co. a 275,000 lb. per hr. boiler fired by a 570 sq. ft. chain-grate stoker was installed. This topping extension includes a 12,000 kw. 1200 lb. 900 deg. F. turbine exhausting to an older 15,000 kw., 200 lb., 500 deg. F. machine

Omaha Topping Extensions

To provide firm capacity for increasing load, without committing itself to a large plant extension or new development, the Nebraska Power Co. authorized, early in 1936, a 1200 lb. 900 deg. F superposed extension to its Jones St. Omaha station. This included one 10,000/12,500 kw. turbogenerator, exhausting normally to an existing 15,000 kw., 200 lb. unit, and supplied with steam by a single boiler unit equipped with economizer, airheater and traveling grate stoker.

Traveling-grate stokers were chosen for the Jones Street station extension, this type of burning equipment having been demonstrated as reliable and efficient for fuels available. For previous installations furnaces had been divided in two sections, each with its own stoker, separated by low dividing wall, but experience indicated that a single stoker unit, even though of the maximum size yet installed, would give reliable service, would simplify the installation and avoid the undesirable partition wall.

Design heat rate of combined high- and low-pressure units, with 25,000 kw. generation, is 12,800 B.t.u. per kw-hr. net output. From beginning of operation in February, 1937, to close of the year, the high-pressure turbine was on line about 70 per cent of elapsed time, and boiler 80 per cent of elapsed time. It is anticipated that service availability of turbine and boiler will be better than 90 per cent. A brief description of this installation was included in Combustion, September, 1936.

Back-Pressure Plant Serving Packing Houses

Nebraska Power Co. has over a long period supplied electrical requirements of packing companies in South Omaha. The packing houses use large quantities of low-pressure steam for process and heating service. Contracts were worked out, between Nebraska Power and Armour & Co. and between the power company and Swift, looking to construction, by the power company, of a steam station near packing houses to supply them with steam and electrical energy. These contracts take advantage of economies made possible by generation of by-product electrical

energy from process steam, and equitably distribute the resulting benefits between the parties to the contract.

Equipment of the new plant comprises, for the present, one 5000 kw. 450 lb. 750 deg. F. turbogenerator, with steam extraction at approximately 175 lb. and exhausting at 30 lb. (gage), supplied with steam by two semi-outdoor boilers. Boiler units include regenerative-type airheaters. Operating space in front of and between boilers is housed, for protection of operators, and each boiler is protected by a canopy, with remainder of setting exposed to weather. A Zeo-Karb water-softening equipment, sufficient to supply 100 per cent makeup, is provided. South Omaha plant and equipment were briefly described in Combustion January, 1938.

Semi-Outdoor Spray-Pond Plant in Kansas

Kansas Gas & Electric Company, requiring additional power capacity to firm up existing plants for increasing load, late in 1936 authorized design and construction of a new plant in North Wichita to be known as Ripley steam electric station. Work on this development is now going on, looking to operation by the summer of 1938. As in Texas, condensing-water cooling is a serious problem in Kansas, and a cooling pond, spray pond or cooling tower is necessary.

The Little Arkansas River provides the most reliable source of makeup, of not unreasonable hardness, in the vicinity of Wichita, and new station is located on this stream, utilizing cooling towers for circulating water and taking makeup from river. An alternate water supply is from wells. An economic analysis of cooling tower and spray pond, for artificial cooling of condensing water, showed a quite close comparison between the two, with lower investment for the former.

Ripley station design is somewhat similar to that described above for Mountain Creek, steam conditions being identical. The turbine is rated normally at 23,000 kw., being supplied by two integral-furnace boilers equipped with airheaters, burning natural gas with oil reserve.

As for Mountain Creek station, turbine room and auxiliary bay are compact structures, housing turbogenerator, condenser and auxiliary equipment. The turbine-room crane is fully housed, instead of utilizing the gantry type and roof hatches as at Provo. Head room, however, is kept to a minimum by using a spreader suspended from the crane hook. Boilers are protected overhead by a canopy, with sides coming part way down, and operating space along one side of steam generating units is housed for protection of operators. Construction work is now under way, looking to plant operation during the summer of this year.

Among the earlier high-pressure superposed installations in this country was an extension to Deepwater, the main central station of Houston Lighting & Power Co. which serves Houston and vicinity. This was put into operation in 1931, bringing total capacity up to approximately 150,000 kw. The installation included a 12,000 kw., 0.8 p.f., 15,000 kw., 1.0 p.f., 1250 lb., 720 deg. F., 3600-r.p.m. "topping" unit, exhausting to a 330 lb. header supplying low-pressure machines, and utilizing full steam-to-steam reheat between high- and low-pressure machines.[3]

Deepwater plant, and new mill of Champion Paper & Fibre Co., are both located on Ship Channel a few miles from Houston. About 2 yr. ago a contract was negotiated covering supply of steam and electrical energy by the power company to the paper company. Boiler capacity at Deepwater was available for paper company service, and a cross-country pipe line was constructed connecting the Deepwater and Champion plants. Steam turbines and auxiliary equipment were

[3]Heat-balance and other data regarding station were given in the December 15, 1930 issue of Power Plant Engineering. The high-pressure boiler plant consists of two 1450 lb., 820 deg. F. boilers which supply steam through a thoroughfare steam reheater to the 15,000 kw. turbine. This reheater reduces temperature of steam for topping turbine from 820 to 710 deg. F., and together with a condensing reheater, reheats the turbine exhaust from about 460 to 710 deg. F. An article in the February and March 1936 issues of Southern Power Journal gave additional details as to design, operating characteristics and experience.

Table I. Principal data on seven new stations of the Electric Bond & Share Group

OPERATING CO.	STATION	LOCATION	INITIAL OPERATION	THROTTLE PRES. LB/IN²	THROTTLE TEMP. DEG.F	BOILERS NO.	BOILERS CAPACITY LB./HR.EACH	BOILER SUPERHEATER SQ. FT.	BOILER SUPERHEATER SQ. FT.	BOILER SUPERHEATER T. CONTROL	ECON. SQ.FT.	AIR HEATER SQ.FT.	AIR HEATER TYPE	W.W. SQ.FT.
NEW PLANTS														
DALLAS POWER & LIGHT CO.	MOUNTAIN CREEK	DALLAS, TEXAS	1938	865	825	2	200,000	13,800	2400	BYPASS DAMPER	1500	19,600	REGEN.	INCL. IN BLR. SURF.
UTAH POWER & LIGHT CO.	PROVO	NEAR PROVO, UTAH	1936	400	750	1	200,000	18,800	3900	———	———	———	———	2800
NEBRASKA POWER CO.	SOUTH OMAHA	OMAHA, NEBRASKA	1938	465	750	2	200,000	11,800	3200	BYPASS DAMPER	———	20,000	REGEN.	3300
KANSAS GAS & ELECTRIC CO.	RIPLEY	N.WICHITA, KANSAS	1938	650	825	2	175,000	10,900	3400	BYPASS DAMPER	———	11,400	REGEN.	2100
PLANT EXTENSION														
NEBRASKA POWER CO.	JONES ST.	OMAHA, NEBRASKA	1937	1200	900	1	275,000	12,000	9700	BYPASS DAMPER	18,100	12,300	REGEN.	3500
HOUSTON LIGHTING & POWER CO.	GABLE ST.	HOUSTON, TEXAS	1939	850	900	1	250,000	10,500	8800	BYPASS DAMPER	6200	39,000	TUBE	1700
NEW ORLEANS PUBLIC SERVICE INC.	MARKET ST.	NEW ORLEANS, LA.	1938	885	900	1	385,000	20,800	9300	BYPASS DAMPER	4000	38,200	REGEN	4100

STATION	FURNACES VOL. CU. FT.	FURNACES H.REL'SE B.T.U./CU. IN.	FURNACES TYPE FIRING	AUXILIARIES F.-D. FANS / BLR. NO.	F.-D. FANS C.F.M. EACH	F.-D. FANS IN.H_2O	F.-D. FANS DEG.F	AUXILIARIES I.-D. FANS / BLR. NO.	I.-D. FANS C.F.M.EACH	I.-D. FANS IN.H_2O	I.-D. FANS DEG.F	B.F.PUMPS NO.	B.F.PUMPS ML.B./HR.EACH	GENERATING UNITS NO.	RATING KW.	SPEED R.P.M.	B. PRES. IN. OF LB.ABS.	COND'SR SQ.FT.	GEN. COOL.
MOUNTAIN CREEK	7100	36,000	GAS & OIL	1	92,800	10.4	120	1	98,200	9.8	315	3	212	1	31,250	1800	1.5	27,100	AIR
PROVO	8900	49,400	C.O. STOKER	1	90,400	3.8	100	2	102,900	8.3	655	2	280	1	15,000	1800	L.O	16,300	AIR
SOUTH OMAHA	8800	36,900		1	92,700	10.7	100	1	103,600	9.8	360	3	300	1	5000	3600	45.0	———	AIR
RIPLEY	6100	34,000	GAS & OIL	1	49,100	10.75	100	1	90,500	8.6	360	3	200	1	23,000	3600	1.75	29,150	AIR
JONES ST.	9400	37,600	C.O. STOKER	1	96,000	8.0	100	2	78,500	13.2	300	2	330	1	10,000	3600	215.0	———	AIR
GABLE ST.	10,000	34,000	GAS & OIL	1	87,000	10.8	100	1	110,000	7.7	325	3	100	1	25,000	3600	2.0	24,000	AIR
MARKET ST.	17,400	29,100	GAS & OIL (P.C.)	2	59,500	9.5	100	2	96,500	11.8	305	3	200	1	30,000	3600	1.4	36,900	HYD.

installed by utility in the latter station, and steam from these turbines is utilized by the Champion Co. in process work, together with "by-product" energy developed.

Pipe conection between plants, about 5000 ft. long, included a 14 in. line carrying 350 lb. steam and a 4 in. return line for condensate; pipe joints were welded and bends utilized for expansion. Insulation for steam line consisted of 1½ in. of high-temperature material and 2 in. of 85 per cent magnesia; for the condensate line, 2 in. of 85 per cent magnesia. Weatherproof covering was of asphalt-saturated rag felt with a mica surface and fastened by galvanized iron wire. The line was supported by light steel structures on concrete piers over normal terrain, and on pile bents across a bayou and nearby swampy region.

Figure 7 shows standard low section of line, rising to the bayou crossing at the right hand corner of the photograph. The turbines installed included one machine rated at 4000 kw. exhausting at 30 lb. ga., and a 5000 kw. unit exhausting to a condenser which supplies hot water for process purposes. A brief description of the installation was published in Power, July, 1937.

850-Lb. Plant Extension in Houston

An extension to the older Gable Street plant serving Houston has recently been authorized by the Houston Lighting & Power Co. A comparison between superposed and condensing units and of various locations for new capacity, and a study of steam conditions, led to the choice of a 25,000 kw. 850 lb. 900 deg. F. condensing turbine. Fuel will be natural gas, with oil reserve. Economy of new station unit is estimated at about 12,400 B.t.u. per kw-hr. net output, with high load factor operation.

As turned out best for Kansas, cooling towers will be used for cooling circulating water, as the stream upon which the plant is located carries insufficient water for direct condensing. Forced-draft cooling towers are particularly advantageous in southern Texas, where wet-bulb temperatures may be high for extended periods, and air motion slight.

Turbine and auxiliary equipment will be housed in an extension to the existing building and is designed compactly for economy. The unit will be supplied with steam by one semi-outdoor boiler, with canopy above, located adjacent to auxiliary bay and utilizing latter as space for operator. The boiler unit will include economizer and airheater; forced- and induced-draft fans will be placed outdoors, with motors designed for such installation. The Houston extension, therefore, as in case of other stations discussed, will take advantage of economies arising from adoption of outdoor boiler equipment, and from providing only minimum size of structure for housing other apparatus. Great care is however exercised, in all these designs, to maintain proper space around equipment, for operating and maintenance functions. The construction program for Houston calls for operation of this station during spring of 1939.

Condensing Installation in New Orleans

When increase of load on New Orleans Public Service system showed need for additional capacity, to operate during 1938, an economic analysis was made, comparing "topping" with condensing extensions to existing Market Street plant, comparing various sizes of unit and various steam conditions, and making sure that plant extension rather than new station was best solution. The study resulted in choice of 850 lb., 900 deg. F. for a condensing unit, the size chosen being 30,000 kw. at 0.8 p.f., 37,000 kw. at 1.0 p.f. Heat-balance computations for new unit call for an economy of approximately 12,000 Btu. per kw-hr. net output at normal load, with 1.4 in. back pressure.

This turbine will be housed in a new structure, built between the existing turbine room and boiler house. For a single new boiler, to burn natural gas and oil or, in the future, powered coal, it was found that space available in the existing boiler house could by utilized. Construction work on this extension is under way, the program calling for trial operation this spring.

A number of minor steam jobs have been carried on by other client companies during the past few years, among them the installation of second-hand turbo-generators at two different plants, to serve as low-load-factor or reserve units. An additional advantage of utilizing these old units was that they could be obtained and put into service in a minimum time. Rugged and properly maintained turbogenerators, of designs such as were put out 15 or 20 yr. ago, are entirely suitable to serve as reliable standby capacity, and their installation, under conditions such as obtained in these two instances, meant a low-cost and otherwise economic safeguarding of service.

The writer wishes to acknowledge the broad and cordial cooperation of executives and engineers connected with client companies, in working out design details of semi-outdoor pants and other new types of installation, and in accepting these relatively novel designs, in the interests of economy.

A. S. T. M. Committee D-5 on Coal and Coke, recently approved for presentation to the Society for publication as a tentative standard, a scheme of sampling coals classed according to ash content. This method is intended to apply to average commercial sampling of coal and is designed to give results so that 95 per cent of the test results fall within 10 per cent of the true ash content of the coal samples. The method also gives instructions for sampling for purposes requiring special accuracy, such as classification of coals by grade or rank and for performance test work. Coals are divided into groups according to size and each group is subdivided according to ash content. For each size and range of ash content, the method specifies the minimum number of increments to be taken in collecting gross samples; also the minimum weight of each increment is given together with the minimum weight of gross samples.

This method of coal sampling is the result of a number of years' intensive investigation by coal consumers and coal producers to develop a practical method of coal sampling, scientifically sound in principle, whereby coals can be sampled with the minimum cost and yet with satisfactory accuracy for commercial purposes.

Colloidal Fuel*

By F. W. GODWIN

Director of Coal Research
Research Foundation of Armour Institute of Technology

AS EARLY as 1879 a suspension of powdered coal in oil was suggested as a liquid fuel. The matter seems to have received little serious investigation until about 1912 when a British patent was granted on a mixture of coal, oil and glue. In 1913 an attempt was made to produce a true colloidal suspension of coal in oil by grinding the coal to colloidal dimensions. Aside from the technical difficulties involved, however, the cost of grinding coal with existing equipment to the ultramicroscopic size required for true colloidal condition was found to be enormous. Fortunately, it has since been shown that such exceedingly fine grinding is not necessary in the production of coal-and-oil suspensions and that stability can be attained in other ways. The term "colloidal fuel", although not strictly correct as applied to the types of suspensions under consideration in recent years, doubtless will remain in use for the sake of convenience.

Until now experiments with colloidal fuel have been motivated chiefly by a need for conservation of oil. This was true in this country during the war and has been so at all times in England where use of oil means importation. Only recently has the development of such a fuel for the sake of its own attributes and as a means of disposal of coal fines begun to receive serious attention.

Heat Per Cubic Foot

The advantages of liquid fuels for many purposes are well known. Chief among them is their ease of handling. The familiar curves showing the trends in consumption of solid, liquid and gaseous fuels would present a very different story if all coal could be moved in pipes and pumps. Then there is the item of storage space. Coal of very high quality may furnish 7.0 therms per cu. ft. while fuel oil will run about 10.7 therms per cu. ft.

Colloidal fuel has been found to possess the handling properties of oils. In laboratory tests and large scale trials it has been piped, stored, pumped and burned in equipment originally designed for oil. Its heat content per unit volume is about 11.2 therms per cu. ft. or approximately five per cent greater than that of good fuel oil. The fire risk in storage of colloidal fuel is less than is possible with either coal or oil alone. As has been suggested, because of its high specific gravity (1.04-1.08) it can be protected with a shallow water seal.

From the standpoint of the operators of the vast coal deposits of the United States the properties of colloidal fuel offer a much-sought opportunity for at least partial recovery of a number of such markets as certain divisions of the ceramic industries wherein only a fluid fuel can offer the required closely controlled, even heat. In the transportation field, where efficient utilization of fuel storage space is essential, colloidal fuel has every advantage. Production of such fuel by a coal operator would enable him to deal with virtually all stationary power plants except those equipped for gas.

*Presented at the Midwest Power Conference.

Economic Status of Colloidal Fuel

From time to time writers have expressed opinions on the economic status of the proposed fuel. In few cases calculations have been presented to show whether conditions would permit its entrance in the fuel market. These have, on first glance, given the impression that its manufacture should await a somewhat greater spread between the prices of coal and oil. Closer inspection reveals that certain variables concerned with local conditions have been overlooked or possibly omitted in an effort to get a world-wide viewpoint. Taking these into account in a new treatment, an equation may be developed to be used in considering the value of a colloidal fuel preparation plant operated in a selected location and supplying a given market.

If Pc is the cost of coal to the producer in dollars per ton, Po the price of oil in dollars per barrel including freight to the preparation plant, Cg the cost of grinding and preparing the coal in dollars per ton, Cm the cost of mixing and stabilizing the colloidal fuel in dollars per ton of finished fuel, F the freight on the finished fuel from the preparation plant to the marketing point in dollars per ton, Hc the heating value of the coal in B.t.u. per pound and Ho that of the oil used, k the tons of coal used per ton of finished colloidal fuel, and d the density of the suspending oil in pounds per gallon, we can write the cost of colloidal fuel at the market as:

$$(a)\quad \frac{k(Pc+Cg)+\frac{(1-k)}{d}47.62Po+Cm+F}{0.0002\ (kHc+[1-k]\ Ho)}\quad \text{Cents per therm.}$$

This relationship, adapted from a similar one offered by Schultes, contains the modifications necessary to allow calculation of the cost of colloidal fuel at the point of consumption with variation in the location of the preparation plant.

For a preparation plant operated by coal producers at the Southern Illinois mines and serving the Chicago market, the cost of coal may be charged at about $1.40 per ton at the mine. This figure is allowed as a probable overall production cost and does not take into account the fact that the fine coal is being sold for less than half this price. The cost of the oil to be used, including freight to the Southern Illinois plant, may be taken as $1.60 per 42-gallon barrel. An estimate of the cost of preparing the coal for suspension, based upon present grinding costs, places this item at about $0.50 per ton. The mixing cost is taken as $0.14 per ton of finished fuel, as has been suggested by Manning and Taylor. Tabulating the foregoing and other variables, then, we have:

Pc = $1.40	Hc = 13,500
Po = $1.60	Ho = 19,000
Cg = $0.50	k = 0.50
Cm = $0.14	d = 8.0

Fuel oil in Chicago, at $1.76 per barrel, sells at about 2.76 cents per therm. A colloidal fuel of 50:50 composition prepared at Southern Illinois and sold at Chicago for the same price per therm would yield from equation (a) the relationship

(b) $$F = 0.0276 \times 325 - 5.85 = \$3.12$$

Thus under these conditions the coal producer can prepare such colloidal fuel at the mines, ship it to Chicago, pay a freight rate as high as $3.12 per ton and receive a return of $1.40 per ton of coal used. Today the producer is getting less than half this price for that portion of his coal which is best suited for colloidal fuel preparation. Indeed, while the recent Federal price code was in effect he could not sell much of it at all.

The permissible freight rate calculated in equation (b) is not necessarily that which would be demanded. Rough calculated predictions based upon existing rates on the oil and coal suggest a rate of $3.22 from Southern Illinois or $3.07 from Central Illinois.

An even more striking calculation can be made for a preparation plant located in the Chicago area. In this case no speculations need be made regarding freight rates since both oil and coal must be transported to the plant at rates already in effect. The oil in Chicago will cost the plant $1.76 per barrel, freight included. Coal charged at $1.40 per ton at the mine plus freight to the plant will amount to $3.45 per ton for Southern Illinois coal or $3.20 for Central Illinois coal. With the plant so located, no freight need be charged against the finished fuel itself, hence the term F becomes zero. Substituting these changed costs in equation (a) discloses that in disposing of his fine coal at $1.40 per ton, the producer can offer colloidal fuel made from Southern Illinois coal at 2.26 cents per therm or, if made from Central Illinois coal, at 2.21 cents per therm. For coal having a heating value of 12,000 B.t.u. per pound, the same calculation yields figures of 2.37 cents and 2.32 cents per therm for colloidal fuels made from Southern and Central Illinois coals respectively. If colloidal fuel were to be sold for the 2.76 cents per therm that oil is bringing, the coal producer would receive $5.85 per ton for the fine coal which at present he is glad to sell at from forty to seventy cents per ton. This offers ample leeway for advertising costs and for competitive pricing in the market.

Experiment has demonstrated beyond a doubt that colloidal fuel can be used in ordinary oil-handling and oil-burning equipment. Investigations have included thermal efficiency and boiler capacity studies as well, the results of which can be summarized by saying that colloidal fuel can be made to yield figures comparable with those of oil. Moreover, with proper air adjustments and reasonable combustion space the material burns with a white, smokeless flame.

Preparation of Stable Product

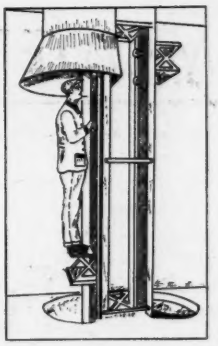
The research problem of colloidal fuel is now one of preparation of a stable product at the lowest possible cost. The principal property demanded is a stability such that no appreciable amount of the powdered coal will settle out of the suspension during the period of storage and utilization. Since fuel is sometimes subjected to rather long storage periods, a product which cannot retain its stability for at least a year should not be considered unless specifically intended for consumption within a shorter length of time. The fuels used in the several tests previously mentioned and in various other trials have shown stabilities ranging from a few weeks to several months. Stability can be brought about in a considerable variety of ways by making use of viscosity, maximum particle size and auxiliary colloidal and surface phenomena. For commercial success in a given geographical region, it must of course be achieved by the use of material economically at hand.

Laboratory studies leading to a sufficiently stable colloidal fuel, as well as later production-plant control, call for some method of measuring stability other than waiting a year to see whether the coal will settle out of suspension. An apparatus suggested by the British Fuel Research Board allows a tube of the fuel under test to swing as a pendulum, so that settling of the coal causes a lowering of the center of gravity and manifests itself in a changed period of vibration. Using a modified form of this instrument which has recently been built at the Research Foundation of Armour Institute of Technology it has been possible to detect without difficulty a settling of coal particles through a distance of less than a tenth of a millimeter. Still finer measurements may be made if required. Thus with this instrument together with the established fuel testing methods means are at hand for the proper evaluation of colloidal fuel in research and production.

Estimates of coal preparation costs used in equation (a) were drawn from present-day costs of preparing pulverized coal in installations using the storage system. In a colloidal fuel of 50 per cent coal approximately $0.50 per ton of coal or $0.25 per ton of finished fuel must be charged to reduction of the coal to the proper fineness for suspension. Probably the greatest single item of this cost represents energy wasted in the grinding operation. Inevitable improvements in crushing and pulverizing methods can be expected to yield still greater returns in colloidal fuel manufacture. The Research Foundation is conducting work in this connection, the results of which are not yet ready to be announced.

The ash content of colloidal fuel is not expected to offer any serious difficulties. In amount it naturally will fall between the ash values for the particular coal and oil employed, provided that no effort be made to reduce it. The reported scale tests in which boilers have been fired with colloidal fuel have indicated that the fate of the ash is much the same as in pulverized coal firing, all effects being diminished to correspond with the smaller quantity present. The use of colloidal fuel in ceramic firing and in the recently proposed Diesel engine operating will undoubtedly demand ash reduction. The fine state of division of the coal, however, affords an opportunity for high-recovery cleaning almost to the inherent ash level, and a number of possible methods are under investigation at this time.

Service Elevators in the Power Plant



The easy way in an African plant

SERVICE ELEVATORS, or as they are frequently called "man elevators", are used to a considerable extent in various industrial buildings but are seldom used in power plants where they are particularly adaptable because of their low cost, small space requirements and facility with which employees may go from floor to floor. For this reason the recent installation of such an elevator in the Vereeniging power station in South Africa is unusually interesting.

Vereeniging is one of the older stations of the Victoria Falls & Transvaal Power Co. but has been continually improved and now has a total capacity of 140,000 kw. in six units. Steam at 240 lb., 660 deg. F. is supplied by 27 B. & W. boiler units with a total steaming capacity of about 1,800,000 lb. per hr. The station operates base load with the load swings taken by the newer Witbank and Klip Stations.

The company supplies a transmission system serving the Witwatersrand area from five stations. The first two stations, Brakpan and Simmer Pan, are located in the Witwatersrand, but, due to scarcity of water, later stations were built farther away where both coal and water are available. The first of these outside stations, Vereeniging, is about a mile from a coal mine and is on the Vaal River which supplies an abundance of cooling water at an average temperature of about 74 deg. F.

This coal, running about 8,850 B.t.u. per lb., as received, has a high ash content of about 24 per cent and the station uses about 2.6 lb. per kw-hr. The generator voltages of 5 and 10 kv. are stepped up to 20 kv. for local distribution and 80 kv. for transmission to the Rand where it is used almost entirely by the various gold mining companies.

The elevator itself, an Allis-Chalmers Nordyke, consists of a 12 in. continuous belt, the vertical distance between the center of the top or driving pulley shown by Fig. 2 and the tail pulley being 74 ft. 6 in. The belt operates continuously at a speed of approximately 90 ft. per minute and is equipped with one-man passenger steps about every 18 ft. Details of one of these steps is shown near the bottom of Fig. 2 and the method of using the elevator is illustrated by the small sketch above. As in the case of a regular elevator shaft, the holes through the floor are enclosed in a heavy metal screw cage which for simplicity has been omitted in the sketch. A hand grip is also provided at a convenient height above the steps. The elevator may be stopped at any location by means of a control rope at the side of the belt while a safety switch prevents passengers being carried beyond the top floor. Passengers may ride either up or down, several may ride at one time and any passenger may alight at any floor without delay.

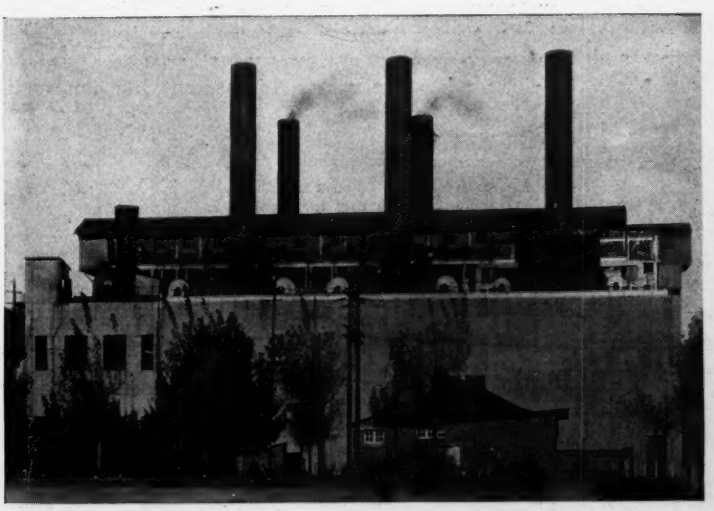


Fig. 1. Exterior view of the Vereeniging Station, one of the older stations on the Victoria Falls & Transvaal Power Co. system supplying power to the South African gold fields. The station operates base load with a load factor of about 85 per cent. The installed capacity of about 140,000 kw., in 6 units, is supplied with 240 lb., 660 deg. F. steam by 27 B. & W. boilers with a total capacity of about 1,800,000 lb. of steam per hr. (Photos, courtesy Allis-Chalmers Mfg. Co.)

Fig. 2. A 12 in. service elevator, installed on 74 ft. 6 in. centers in the Vereeniging Power Station

MODERN TURBINES

Fundamentals of The Turbine-Generator*

By
J. M. LYONS
Generator Engineering Dept.,
General Electric Co., Lynn, Mass.

SINCE the turn of the century the turbine-generator has become an indispensable part of our industrial and community life. By taking full advantage of the high rotational speeds possible so far only in the turbine type of prime mover, designers have steadily made both the turbine and the generator more compact, more easily assembled, and better looking. Furthermore, they have been able to make units of larger ratings than could be powered in any other way, and have recently produced units of larger size at higher speeds than had ever been made before.

During this amazing development from sets of a few thousand kilowatts at 900-1200 r.p.m. up to modern sets of 160,000 kw. at 1800 r.p.m. and 60,000 kw. at 3600 r.p.m., many serious problems have been successfully overcome. Certain features of design and manufacture which would have been impractical, or even impossible years ago are now accepted without surprise. For example, did you realize that in a modern 3600 r.p.m. generator the total centrifugal force on the center of the rotor shaft may amount to 125,000,000 lb.?—or that enough cool air has to be circulated through a 7500 kw. generator even at 96 per cent efficiency, to carry off heat which would keep 6 or 7 houses comfortable in the coldest winter months? The vast store of knowledge and experience gained in the last 30 yr. provides the necessary foundation for successfully coping with such problems.

At the same time new conceptions of certain design and construction features have arisen. This, of course, does not refer to quality—because quality only goes one way—upward. However, other characteristics which used to be considered important, like close volt-

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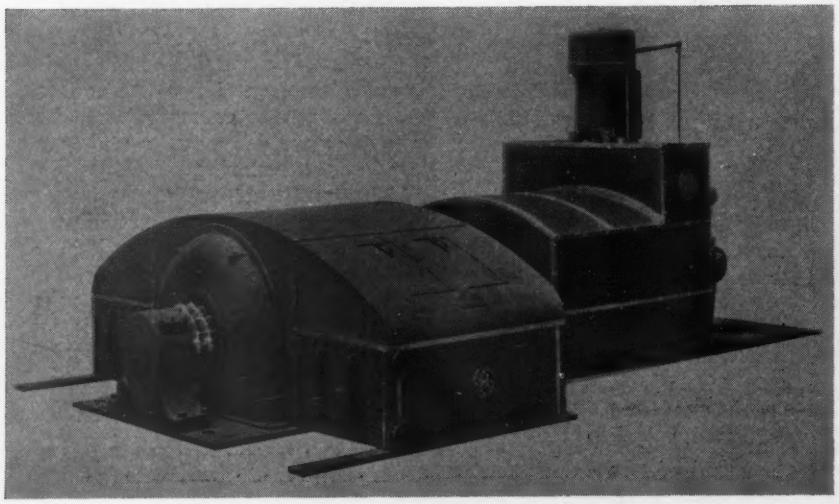


Fig. 1. A modern turbine-generator unit with side mounted air coolers, showing the integrated design of the turbine and generator housings

age regulation, are not considered so now. Extensive studies have been made of others—like stability—and much more is known about the best values and limits for such items.

It is obviously difficult for the average user of turbine generators to keep up with all the many changes which have been made. But with present day conditions it is necessary to have a working knowledge of certain important features of the generator which may vitally affect its application in any particular case. A previous article in this series therefore described some of the fundamentals of turbine generators, while another article presented the necessary physical foundation for understanding the complex subject of stability. This article will continue by telling about generator reactances (often a confusing subject), telephone influence (T.I.F.), and insulation, which plays such a vital part in the life of the generator.

The subject of reactances is often one of the most confusing of the generator characteristics which a purchaser may need to know. The confusion generally arises from a failure to get the physical picture behind reactances. Reactances—and their related "time constants"—are only short cuts for calculating currents and voltage at any point on a system supplied by generators, at any time after a short circuit, a fault, or a change in load. When a short circuit occurs outside a generator the currents which flow from the generator can be calculated with a knowledge of the magnetic field inside the generator, the magnetic "saturation" of the generator, and the resistance of the various windings and circuits. This is a laborious process, however, and it is easier to estimate the reactances and time constants of the generator, which can then be put into relatively simple equations for determining these same currents. The large (and increasing) number of these reactances and time constants results solely from the increasing complexity of power systems, and the number of short circuit or fault conditions which must be accurately checked.

It is therefore important in the present era of more and more complicated systems to know at least what some of these reactances and time constants are, and what values they may have in generators of modern design. A brief summary of some of the more common ones, together with the range of values they may have, and what they are used for, is given in Table I.

These values apply generally to turbine-generators, although some special machines in the smaller sizes,

IT IS CURIOUS that in the design of electrical equipment, particularly electric generators, the one condition that must ever be kept in mind, is the very condition that we hope will never take place. This is the short circuit condition. Who wants a short circuit? Certainly nobody. Yet, as Mr. Lyons points out in this, his final appearance as guest author on this series, generators—that is, good generators—are always designed to withstand short circuits of the most severe nature. Its really not a bad idea,—something like fire insurance,—and there is always some nit wit around a power plant who sooner or later will set his dinner pail on the bus bars.

and some of the larger ratings may fall outside the ranges shown. The reactances of turbine-generators are generally considerably smaller than for slow speed salient-pole generators of the water-wheel type.

The simplest application of reactances is for calculating the sudden short circuit current caused by the occurrence of a short circuit across all three phases of a generator at the terminals of the machine. The maximum instantaneous current after the short circuit occurs is found by dividing the initial generator voltage by the per cent sub-transient reactance. For example, if the voltage was normal (100 per cent) and the reactance is 10 per cent, the current will rise instantaneously to ten times normal, because instantaneous current =

$$\frac{\%\ \text{initial volts}}{\%\ \text{sub-transient reactance}} = \frac{100\%}{10\%} = 10\ \text{times}$$

normal. The current dies away very rapidly at first, and then more slowly. After the first rapid decay (in about 0.1 second), the current is found by dividing the initial voltage by the transient reactance, and then using the proper time constant to calculate the amount the current has decreased from this initial value. Fig. 2 shows a typical short circuit current decrement, or decay, in a turbine-generator.

It is important to note that the above procedure gives the instantaneous current under the most favorable conditions. It is possible for the short circuit to occur at such an instant that the current in one phase may rise as high as $\sqrt{3}$ times that given above (or 17.3 times normal for the example given). This is called a "completely offset" current and is the worst

TABLE I. REACTANCES AND TIME CONSTANTS OF TURBINE-GENERATORS

Name	Symbol	Range of Values	When Used	Used to Determine
Synchronous reactance	X_d	100-140%	Steady-state problems	Steady-state stability characteristics. Sustained short circuit currents.
Transient reactance	X'_d	10-20%	Transients	Interrupting duty of circuit breakers. Transient stability. Voltage dip under transient overloads.
Sub-transient reactance	X''_d	6-15%	Transients	Maximum instantaneous short circuit currents for mechanical design of breakers and generators.
Open-circuit Time-constant	T'_{do}	1.0-5.0 sec.	Transients	Decay of transient part of short circuit currents. Rate of voltage change under transient overloads.

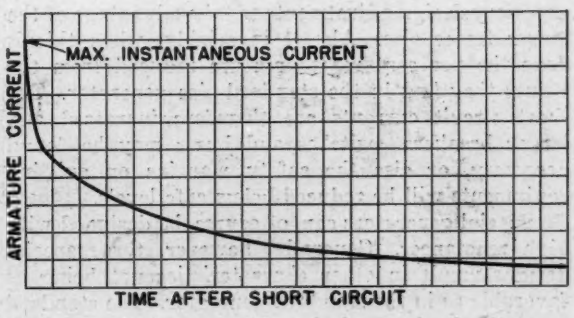


Fig. 2. Typical decrement curve of sudden short circuit current

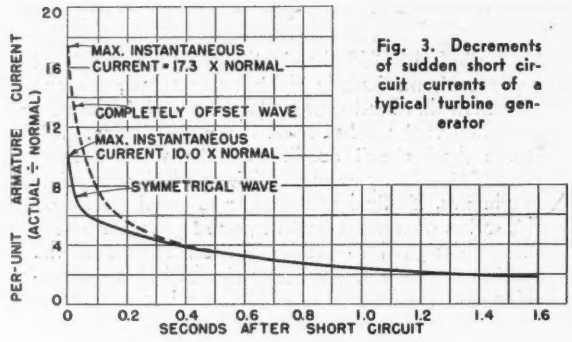


Fig. 3. Decrements of sudden short circuit currents of a typical turbine generator

which can be experienced. The offset condition decreases very rapidly after the short circuit, and the current soon returns to the most favorable or "symmetrical" condition. These two cases are illustrated in Fig. 3 for a typical generator.

The absolute magnitude of the short circuit currents may reach rather startling amounts. For example, it has been calculated that the instantaneous peak value of the short circuit current in one phase of the largest low voltage A-C generator made in this country might reach 200,000 amperes under the worst conditions. These large currents produce mechanical forces on the generator end windings which would twist them out of position if not solidly braced. Actually in modern generators no movements of the coil ends can be observed when the generator is subjected to the shock of such a sudden short circuit.

It is necessary to make plain in a discussion of reactances why sub-transient reactance and transient reactance are both used in short circuit work. The reason is that the *sub-transient reactance determines the maximum current which will flow through generator, leads, circuit breakers, disconnect switches, etc., in the first instant after a short circuit and before the circuit can be opened.* All parts of the circuit must be mechanically strong enough to carry such currents. *The transient reactance, in combination with the proper decrement factor or rate of decay, determines the current which the circuit breakers must interrupt at some specified time after the short circuit.* It is also used in many other transient studies where sub-transient conditions are not present.

As mentioned previously, there is usually some definite relation between generator stability and generator reactances. For example, one common method for increasing generator stability is to build the given rating into a frame size larger than normal, making necessary design adjustments to take advantage of the larger frame size. Almost invariably, when this is done the per cent reactances are reduced from the values they had in the standard size generator. The short circuit currents are therefore increased and larger breakers, switches and buses may be found necessary, or else the safety margins on existing equipments will be reduced below safe levels.

Special generators can, of course, be designed with high reactances. Generally, however, these special designs result in other characteristics not being as favorable as in the standard generator. The standard generator is always designed to have the best overall characteristics, not favoring any one quality at the expense of others equally as important.

The next important characteristic of a turbine-driven generator to be discussed is the telephone influence factor (T.I.F.). This was formerly known as "telephone interference factor". It is a number, determined from readings on a specially designed instrument, known as a T.I.F. meter. T.I.F. indicates the influence which the harmonics in the voltage wave of a generator will have on telephone circuits adjacent to the power lines running from the generator. Although all commercial turbine generators have practically sine wave shapes of current and voltage output (which is the ideal), nevertheless there are always some irregularities (or harmonics) of higher than 60 cycle frequency which can cause hum or other extraneous noises in nearby telephone circuits. The T.I.F.

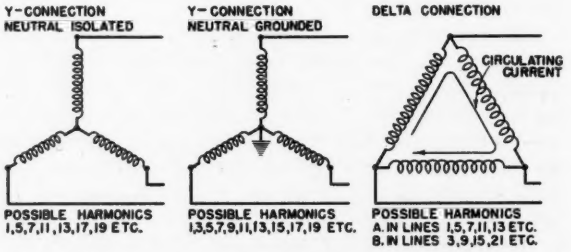


Fig. 4. Generator connections with the harmonics possible in each connection

meter, when placed across the terminals of the generator at normal voltage, receives these harmonics, gives each one a weighting corresponding to how much that frequency is known to interfere with telephone conversations, and produces output readings which represent the composite effect of all the harmonics. The larger the T.I.F. so obtained, the greater will be the possible effect on telephone circuits.

The size and number of the harmonics which a generator will produce can be controlled considerably by the generator design. For example, a generator designed with an armature coil pitch of 66⅔ (two-thirds of full pitch) will not produce any harmonics whose frequency is 3, 9, 15, 21, etc., times the fundamental, or 60 cycle, frequency. While this is desirable, it is frequently impractical to have this coil pitch in a standard design because its use would result in a poorer design from other standpoints.

The generator connections also have an important bearing on the size and number of the harmonics which may be present. If the generator is Y-connected and the neutral is ungrounded, there will be no triple frequency harmonics (3, 9, 15, 21, etc.), in the line voltage of the generator. If the neutral is grounded these can occur. If the generator is delta connected, these harmonics cannot occur in the line voltages, although small circulating currents of these frequencies will flow around the closed delta connection of the generator phases (except for ⅔ coil pitch). Fig. 4 shows graphically how these connections affect the harmonics which may be present.

The question is often raised why a distinction is made between triple frequency harmonics (3, 9, 15,

21, etc.), and non-triple-frequency harmonics. The reason is that triple-frequency currents flowing in the three lines of a three-phase system are all in phase (for each harmonic), so that ampere for ampere they can produce more serious effects on neighboring telephone circuits than the non-triple frequency harmonics which are out of phase with each other. Furthermore, their effects cannot be reduced by transposing the power lines, as is possible with the other harmonics.

Two limits are therefore placed on T. I. F. One is the limit on "balanced" T. I. F., corresponding to the case of Y connection without neutral, or to delta connection where no triple frequency harmonics are present. At present this limit varies with size of generator as follows:

Gen. KV-A.	Allowable Balanced T. I. F.
1000—2500	125
2500—10000	60
10000 and above	50

The other limit is the one placed on "residual" T. I. F., which is the T. I. F. of the triple frequency harmonics alone, measured under such conditions that no other harmonics are present. For machines of 5000 KV-A. and above, this T. I. F. is now limited to 30. For smaller machines no definite limit is set, but it is recognized that such machines operating with grounded neutrals may require special consideration.

Properly designed standard turbine-generators easily come inside these limits, and it is only occasionally that special designs must be made, or special precautions must be taken to guarantee satisfactory operation in unusual situations.

Another important feature of a turbine generator is the insulation of the armature and field windings. The total amount of insulation in an average generator may amount to only one per cent of the total weight. Yet this one per cent usually determines the life of the generator, and the reliability of service it will give.

Insulation of turbine generators falls into two main classes, namely Class A and Class B. The designation should not be misunderstood as referring to the quality of the insulation; since actually Class B is of higher grade than Class A. These are the official classifications of the American Standards Association. Class A refers to any insulation containing cloth, paper, varnish, or other organic material as one or more of the main insulating parts, while Class B refers to insulation containing only inorganic materials like mica and asbestos.

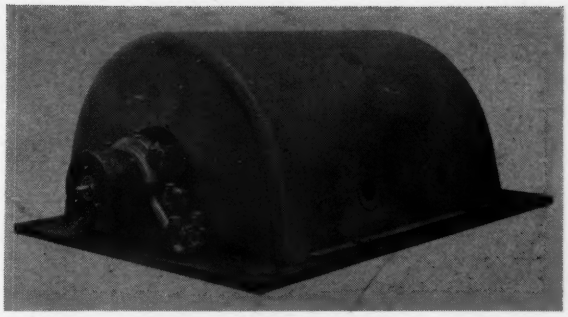


Fig. 5. Turbine-driven generator of modern design with stream-lined casing and end shields

The armature windings of turbine generators may have either type of insulation, depending on size and weight of the coils. The smaller units (up to about 3000-5000 kw.) with voltages up to about 5000 v. generally employ Class A windings. For higher voltages, and for all larger generators Class B is universally used. Class B can of course be used on the smaller sizes if warranted by unusual operating conditions (climate, severe voltage disturbances, etc.).

In the best modern generators using Class B armature windings, each individual coil is insulated with mica tape wrapped spirally around the whole length of the coil, impregnated with an asphaltic compound under heat and pressure to eliminate air pockets, and covered with heavy asbestos tape for mechanical protection. It is startling to realize that on a 7500 kw., 13,800 v. generator the total amount of mica tape required on the armature coils, if strung out in one length, would extend for 30 miles, yet it occupies a space only about one quarter inch thick around each coil.

Rotor windings of high speed turbine-generators offer a different problem. Class B insulation is always used on these coils because they are subject to heavy pressures and must be allowed to run at higher temperature because of the restricted heat flow paths in the rotor. The rotor winding temperature is allowed to reach 125 deg. C., while the stator windings are limited to a total temperature of 100 deg. C.

An idea of the pressures applied to the rotor winding insulation on a 7500 kw., 3600 r.p.m. generator at full speed may be gained from the fact that it is

(Continued on page 391)

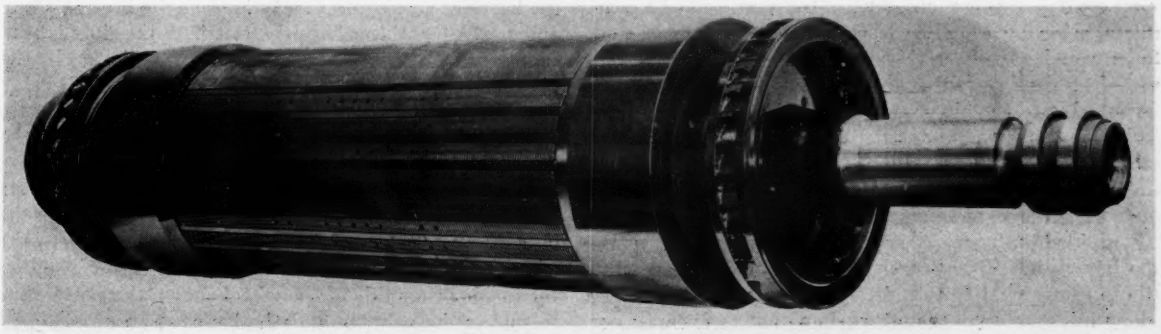


Fig. 6. Rotor of modern high-speed turbine-driven generator

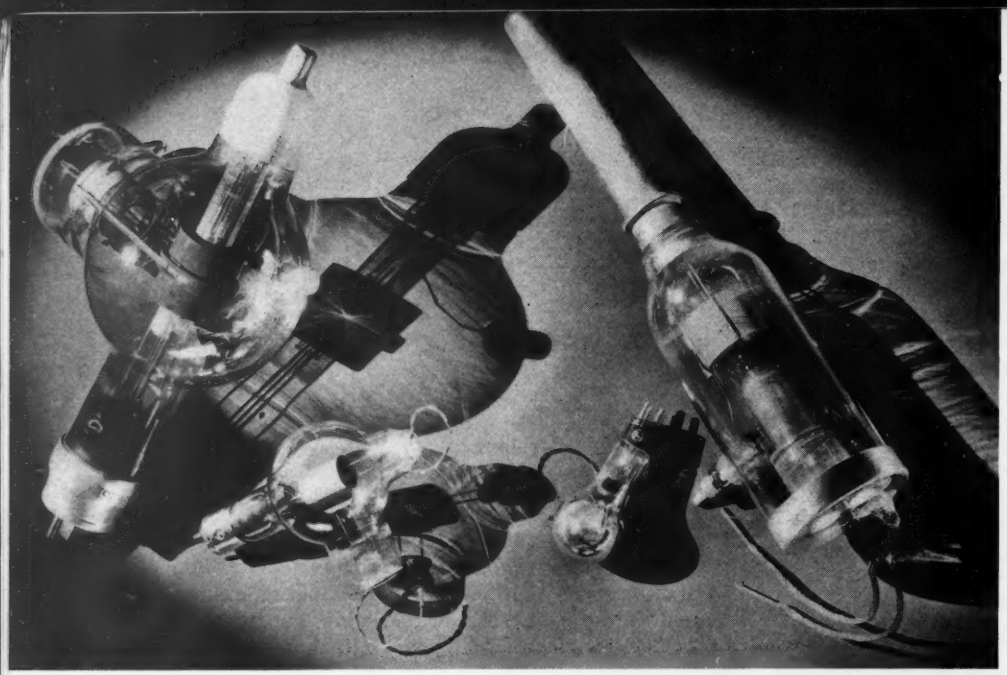


Photo Courtesy General Electric Co.

Electron T

Part XXVI

By

A. W. KRAMER

NOW THAT we have begun to consider the applications of electron tubes, we are reminded of the ancient adage about leading a horse to water but not being able to make him drink. We have endeavored to show you how electron tubes work and what they can be made to do but we cannot tell you just how you can use them. That is something you will have to work out for yourself and the success you will have in that direction will depend entirely upon your enthusiasm, your imagination, your technical skill and, naturally, upon your capacity for using tubes.

Tubes have been applied to many hundreds of different uses in industry. They perform such massive functions as reversing the direction of travel of a red hot, 50 ton ingot of steel in a rolling mill as easily as they check the accuracy of a wrist watch. They are as useful in extending the function of a delicate galvanometer as they are in controlling the stability of a transmission line. Although the application of the electron tube may be thought of as still being in its infancy, it is an extremely precocious infant and it has made its way into more industries than we can enumerate. A number of applications will be described but these will be presented not with any idea in mind that they may be found directly useful; they will serve only to show what can, and has been, done. The field of electron tube applications is already so vast that even assuming there was space available to describe all the present day applications, such a list would not be complete, since by the time it was finished scores of new uses would have been developed.

Most electron tube applications, however, can be grouped into certain classes of use and so, if we consider one or two applications in each group we will obtain a good general idea of the usefulness of tubes in the various branches of the industrial and electrical art. In general, equipment or systems using tubes may be divided into two classes; first, those which would be impossible without the use of tubes and, secondly, those in which tubes fulfill functions which might be done in other ways though perhaps not as cheaply nor as well.

As an example of the first class, consider the clever little device shown in Fig. 1 used for sorting navy beans up in Michigan. Navy beans, whether you happen to be a connoisseur of lentils or not, must be white and perfect, not discolored or spotted in any way. It is said that a single discolored or imperfect bean in a traditional bean pot on a Saturday night is sufficient to throw a truly Boston household into the wildest consternation. So beans must be white and perfect and before the device shown in Fig. 1 was invented, girls used to sort beans by hand, from morning till night. The beans would come along on a conveying belt and the discolored ones would be removed as they passed by the girl inspectors. It was tedious work, and working all day they sometimes earned as much as $1.25 a day.

Now, thanks to the electron tube, this bean sorting is done automatically and the girls probably are on relief, or married—victims of technological unemployment. The beans are placed in a hopper through the lower part of which the periphery of a hollow wheel passes as shown. The periphery of this wheel is pierced with small holes and a vacuum is applied to the inside of the wheel so that in passing through the hopper, by virtue of the suction, a bean attaches itself to each opening. Part of the way round, a small section of the periphery is strongly illuminated by two lamps and as each bean passes under this illuminated spot the light is reflected from the surface of the bean into a photocell. As long as the bean is white and perfect nothing happens but if a discolored bean comes under the area scanned by the photocell, the photocell current varies and trips a relay. This relay energizes a small solenoid hammer which suddenly strikes the inside edge of the wheel and knocks the defective bean off. The action is very fast and there is just enough delay in the system so as to place the discolored bean directly over the hammer when the blow is struck. Good beans are carried along to the lower part of the cycle where a close fitting shoe on the inside or outside of the wheel covers the ports, thus releasing the vacuum and the beans drop off.

When it is known that the number of discolored

Tubes—Principles and Applications

You may not be aware of it, but the electron tube has proved a great boon to the navy bean industry. Perhaps you don't like beans, but whether you do or not the device described in this article typifies of a whole range of electron tube applications; it is as suitable for sorting piston rings as navy beans. The article also shows how tubes have extended the scope and useful application of electrical measuring instruments.

beans in the average bean crop runs between 7 and 20 per cent, the usefulness of these sorting machines becomes more obvious.

This, it will be obvious, is an application of the electron tube that could not be accomplished in any other way because in the phototube we have for the first time a device which takes the place of the eye. Previous to the development of the phototube there was no practical device that would act as a substitute for the human eye in the control of industrial or mechanical operations of any type. The device, of course, also involves the use of amplifying tubes but the phototube is the basis of its action.

The phototube, in fact, is one of the most useful members of the electron tube family as far as industrial uses are concerned. The fact that it operates by means of a light beam which has no inertia enables it to initiate operations by objects which are not touched mechanically and this opens up a vast new field of action. It provides the industrial engineer with a new degree of freedom, one which enables him to couple the whole science of optics to his electrical and mechanical control problems. It gives him not only an inertialess arm or lever but also provides him with a device that responds both to the frequency and the intensity of the light; indeed, it goes further than that for it is sensitive in the ultra-violet region as well. The principal use in industrial work for the photocell, however, is to provide an optical link between a mechanical and an electrical system. An excellent example of this type of application was given in the preceding article where the speed of a centrifuge operating at 100,000 r.p.m. had to be measured. Here the high speed of response of the phototube coupled with the fact that it exerted no drag or load of any kind on the moving body made it an ideal solution to a difficult problem.

Another important field of usefulness for electron tubes of all types is in the field of measurement and instruments. In certain types of instruments such as color analyzers, photometers, exposure meters in photography, the photoelectric element forms the very basis or reason for the instrument's existence since these instruments would not be possible without it. In other cases, the electron tube extends the sensitivity, or field of action, or the performance of existing instruments. In this class are the many types of vacuum tube voltmeters, all of which use standard type ammeters, milliammeters, voltmeters or millivoltmeters in one way or another but which have their field of usefulness greatly increased by the use of electron tubes as amplifiers or rectifiers. Such voltmeters are especially useful in the measurement of small audio and radio-frequency voltages where the use of a power consuming device is unsatisfactory because of the small amount of power in the circuit. As has been explained, the superiority of the electron tube amplifier over all other forms of electrical amplifiers lies in the fact that the grid draws no electrons when it is maintained at a negative potential.[1] In other words, under proper conditions an electron tube circuit need draw no appreciable power from the input circuit, yet

[1]Part V. Page 342, June 1936 issue.

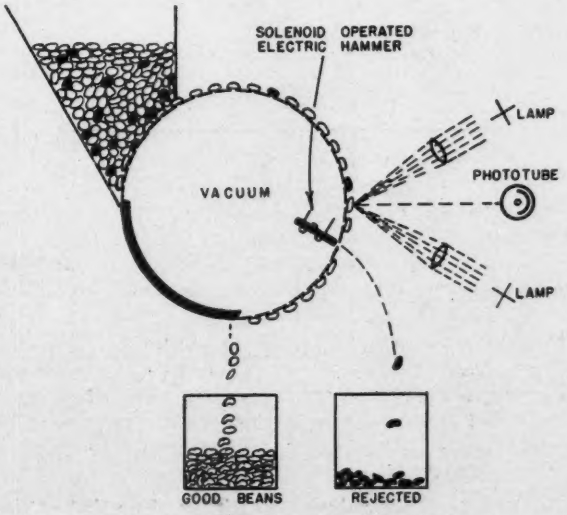


Fig. 1. An Electron Tube Navy Bean Sorter

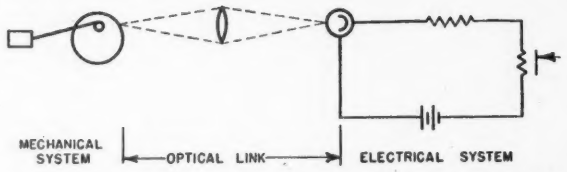


Fig. 2. The principal use of the photocell in industry is to provide an optical link between a mechanical and an electrical system

it will serve as an amplifier. It is evident, therefore, that a voltage measuring device built up of an electron-tube amplifier in combination with a millivoltmeter or milliammeter in the plate circuit could measure small variations of voltage on the input side without disturbing the input circuit in any way. In some cases such voltmeters are designed so that they give direct readings without the necessity of making adjustments; in others, usually where a greater range is desired, manual adjustments have to be made. To take a very simple case of the latter type, consider the circuit in Fig. 3 with a triode biased nearly to the plate-current cut-off, a current of a fraction of a milliampere being taken as a reference, called the "false zero." When a voltage is applied between the grid and cathode, the plate current rises. The grid bias is then increased until the plate current returns to the false zero. The additional bias voltage required to bring the plate current back to the reference value will then be equal to the peak value of the signal being measured.

The sensitivity of such a single-tube voltmeter is somewhat restricted, since accurate measurements cannot be made of low voltages because the plate current change is small. However, a second tube connected as a d.c. amplifier can be added to increase its sensitivity. A wide range voltmeter of this type is shown in Fig. 4.[2]

The input tube T_1 is biased to plate-current cut-off. Tube T_2 is connected to the output of T_1 to act as a d.c. amplifier. The type 80 tube provides the d.c. plate voltage for tube T_1, but the plate voltage for T_2 is alternating, taken directly off the primary of the power transformer. Of course, as in any other case where a.c. is applied to the plate circuit of a thermionic tube, the tube itself acts as a rectifier and half-wave rectified current flows in the plate circuit.

[2]Described in QST for October 1935.

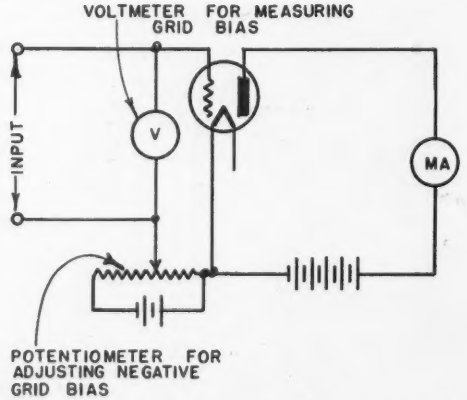


Fig. 3. A simple circuit showing the principle of the electron tube voltmeter

A series condenser C_1 with a shorting switch is provided in the input circuit to isolate d.c. voltages when desired. A shunt resistance R_2 is provided to give the grid a d.c. return when C_1 is used or when the external circuit will not furnish a d.c. path.

The potentiometer, R_1, provides the means for adjusting an external d.c. source so as to give the negative potential necessary to balance the voltage being measured, the value being indicated by the two-range d.c. voltmeter. A small 4½ v. "C" battery

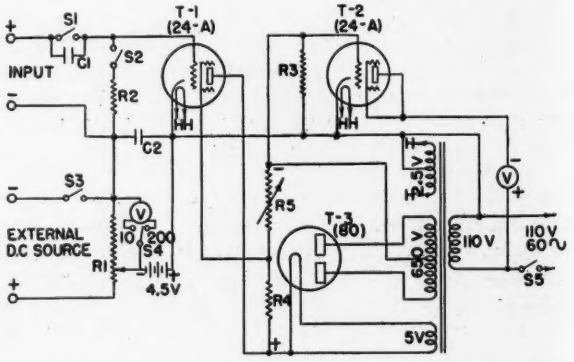


Fig. 4. A wide range, two-tube electron tube voltmeter with D.C. amplifier

C_1—0.001 mfd. mica
C_2—0.001 mfd. mica
R_1—10,000 ohm 6-watt, wire-wound
R_2—1.0 megohm 1-watt
R_3—8000 ohm 1-watt
R_4—15,000 ohm 10-watt, wire-wound
R_5—2000 ohm 2-watt, wire-wound

is wired into the input. Its purpose is to bias tube T_1 to the plate current cut off. Vernier adjustment of the plate current cut-off is accomplished by variation of the screen grid voltage, using R_5 as a control.

R_3 forms part of the output circuit of tube T_1 as well as the input circuit to T_2. With T_1 operating near cut-off the d.c. voltage drop across R_3 is small. With no input voltage to T_1, tube T_2 will be operating at maximum plate current which will be indicated by the milliammeter in the plate current of this tube. A very small increase in plate current of T_1 due to a small voltage applied to the input, will cause a relatively large increase in voltage drop across R_3. This, in turn, will cause a sharp reduction in the deflection of the milliameter in the plate circuit of T_2. By adjustment of R_1 the milliammeter pointer can be brought back to its original reading or "false zero."

This vacuum tube voltmeter is representative of a whole class of circuits which use the amplifying or rectifying properties of tubes for this purpose. It is applicable to the measurement of voltages of all types, direct or alternating, low or high frequency. At the A. O. Smith Corp. in Milwaukee, the electron tube voltmeter solved a rather difficult problem of measuring the voltage across the arc in electric welding processes. In electric arc welding the length of the arc is an important factor in the production of uniform welds and since the voltage across the arc is a direct function of the length, it becomes desirable to check this voltage

continually, especially in training new men and for setting automatic welding heads.

It has been found that the voltage change occurring when the arc changes from the correct to an incorrect length is rather small; furthermore, the open circuit voltage of the welder is usually twice the voltage when the arc is struck. Both of these factors make voltage measurements of the arc difficult with ordinary voltmeters, so the electron tube voltmeter circuit shown in Fig. 5 was worked out by W. Richter,[3] and this gives very satisfactory results in this service. As will be noted, it is a simple circuit using a single 49 dual-grid power amplifier supplied entirely by dry batteries. By means of the potentiometer R_1 R_2 only half of the arc voltage variations are impressed on the tube. A "C" battery is provided for varying the bias on the tube so that different ranges may be obtained. As shown, with two taps on the "C" battery, the instrument covers a total range of from 20 to 44 v. in two steps.

These electron-tube voltmeters will serve to show the principles involved in this type of work. These circuits are particularly valuable in the measurement of extremely weak voltages and where the variations are small. In the measurement of high frequency voltages, the voltages are merely amplified and rectified so that they can be measured by a d.c. meter; in

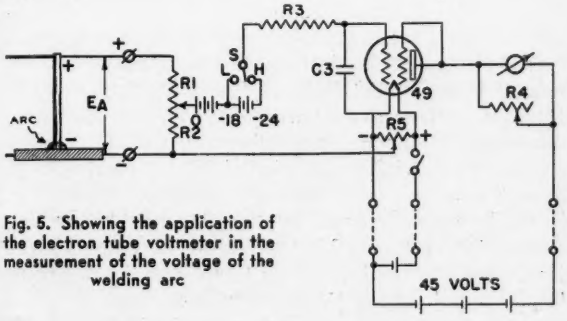


Fig. 5. Showing the application of the electron tube voltmeter in the measurement of the voltage of the welding arc

fact, there is no other way of measuring high frequency voltages.

The principles involved in these voltage measuring circuits are subject to almost infinite variation and modification. The idea of measurement of course implies control and in many instances these electron tube voltmeter principles have been applied in control systems. In special cases, the electron tube voltmeter idea has been incorporated in an electron tube wattmeter for the measurement of extremely small power. In one instance of this kind a push-pull circuit such as that shown in Fig. 6 has been used. The load current is measured by the voltage drop across a small resistance in series with the line and the load voltage by the drop in high resistance across the line. The sum of the instantaneous values of the two component voltages is impressed on the grid of one tube and their difference on that of the other. The micro-ammeter in the plate circuit measures the power supplied to the load directly.

Another interesting wattmeter circuit has been devised by T. B. Wagner[4] by the use of a double grid

[3]Electronics, March 1935.

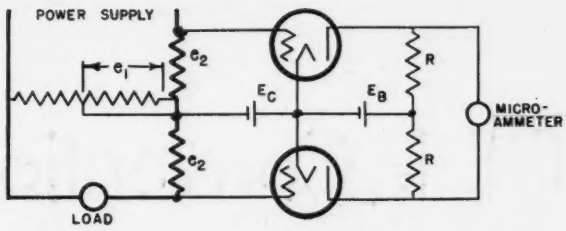


Fig. 6. A push-pull circuit which functions as a wattmeter for the measurement of small power

tube. As shown in Fig. 7, this tube has two symmetrical and therefore equally effective control grids. A voltage proportional to the load current is impressed on one of the grids while the voltage across the load is impressed on the other. In this way the measuring instrument in the plate circuit is made to indicate the power in watts; indeed, it has been found that it will operate not only as a wattmeter but will give voltage, current or power factor as well.

The applications described above are typical of a particular class of electron tube circuits using high vacuum tubes for measuring purposes.

It must not be inferred, however, that the electron tube instrument applications can be substituted for all existing methods of measurement. In most cases they are suitable only for special conditions—conditions which do not permit use of older methods or standard electromagnetic equipment directly. Obviously there is no particular advantage in substituting electronic measuring devices for our standard, electromagnetic instruments, since these are simple, accurate and reasonably priced. But for purposes where these standard measuring instruments do not apply, the electronic methods offer new and far reaching opportunities. As Dr. Hull of the General Electric Co. has put it, "electronic devices enable us to measure, without disturbing them, smaller voltages, smaller currents, smaller distances, smaller times, smaller sounds, and smaller light. Examples of smaller voltages include the transient voltage due to heartbeat and nerve action; of small currents, the ionization due to a single photon; of small distance, the separation of atoms in a molecule; of small time, the breakdown of a spark in air or vacuum; of small sounds, speech transients and the noise of machines; of small light, the radiation from a distant star."

[4]Page 1621, Dec. 1934 Electrical Engineering.

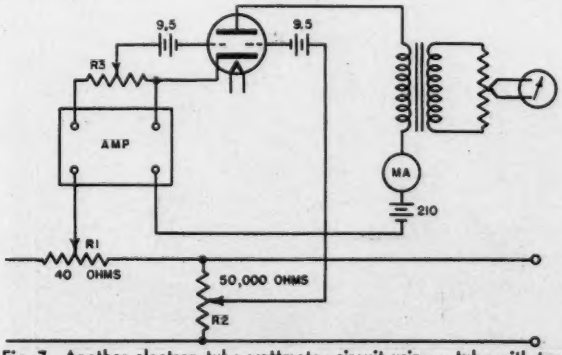


Fig. 7. Another electron tube wattmeter circuit using a tube with two symmetrical control grids

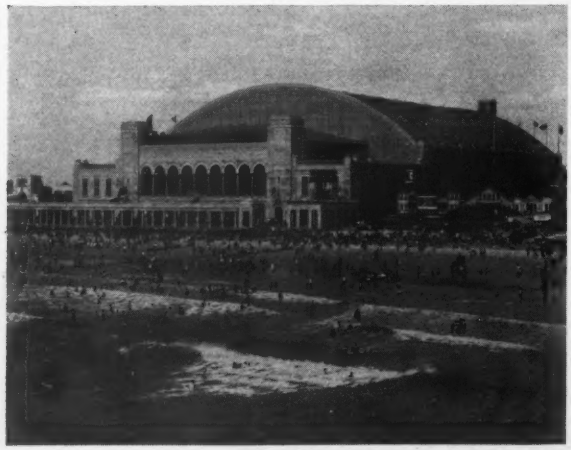
E. E. I. Convention to be Held At Atlantic City Again

AFTER a lapse of three years during which time the annual conventions were held in other cities, the Sixth Annual Convention of the Edison Electric Institute will again be held at Atlantic City, June 6 to 9 inclusive. While all the details of the meeting have not yet been completed the business program has been practically completed and a large attendance is expected.

Since the first convention of the Institute in Chicago in 1933 the attendance has been growing and while poor business conditions might have an adverse effect there are some indications that a new record for E. E. I. conventions might be set. Certainly the industry has many problems that need action and discussion and though business is poor, the position of the utilities is very much better in this respect than that of certain other industries or in fact, than of business in general.

As a consequence of an expected large attendance, the convention will be held in the Atlantic City Auditorium rather than in the assembly rooms of hotels which, even in 1935 were found inadequate to seat the delegates comfortably. Members of the reception committee with the Atlantic City Electric Co. as host have prepared entertainment features which will fill each day with plenty of activity for every delegate and visitor to the convention.

The dominating theme of the meeting will be the outlook in America for private enterprise in general and the problems now confronting such enterprise in this country, questions which are uppermost in the mind of every electric utility man today. Included among them will be discussions of sales questions, sales analysis, trend of costs, advertising, accounting and employee matters. These subjects will be discussed by leaders in their respective fields who have much of value to present to their audiences.



The Atlantic City Auditorium

Of outstanding importance will be the discussions of the outlook for private industry in this country by distinguished economists and utility leaders. A partial list of speakers includes Dr. Virgil Jordan, President of the National Industrial Conference Board, Dr. W. W. Cumberland, partner of Wellington and Co., President Kellogg of the Institute, Floyd L. Carlisle of Consolidated Edison of New York, Inc., J. E. Davidson, Nebraska Power Co., W. H. Harrison, American Telephone and Telegraph Co., H. P. Liversidge, Philadelphia Electric Co,, H. S. Metcalfe, West Penn Power Co., H. A. Snow, The Detroit Edison Co., B. S. Rodey, chairman of the General Accounting Committee of the Institute, Walter H. Sammis, The Commonwealth and Southern Corp., and A. H. Kehoe, Consolidated Edison Co. of New York, Inc.

In the main, the business program will be devoted to the broader aspects of management, public policy, finance and administration. The more technical problems of the industry are not to be discussed at this meeting since it is felt that these are best handled through specialized meetings such as the National Sales Conference in Chicago last March, the National Accounting Conference held recently at Detroit, and the National Conference of the Engineering Committees held in Chicago early in May.

The first day of the Convention, Monday, June 6 will be given over to the registration of delegates, committee meetings and informal work of the convention. The President's Reception will be held in the evening of the same day in the Rose Room of the Hotel Traymore. The opening business session will be held promptly at 9:30 a. m. on Tuesday, June 7th in the Grand Ball Room of the Atlantic City Convention Hall where all sessions of the convention will take place.

One of the high points of the convention will be a Banquet to be held Wednesday evening, June 8th in the American Ball Room of the Hotel Traymore. Messrs. E. A. Lewis, Vice President and General Manager and R. E. Swift, Assistant General Manager of

the Atlantic City Electric Co. are in charge of the arrangements for this banquet. Special entertainment will be provided on Tuesday afternoon for the ladies attending the convention and a dance will be given on Tuesday evening as well as on Monday evening after the Presidents' Ball.

Important discussions of system operation and sales will take place at the general sessions. Walter H. Sammis, vice president of Commonwealth and Southern will outline the sales approach to two important power sales problems—meeting competition and directing sales effort toward the profitable load.

H. S. Metcalfe, director of public relations of West Penn Power, will speak on the present day public utility advertising.

Harry Snow, controller of Detroit Edison Co. will present an analytical discussion of electricity sales.

Factors which have tended directly and indirectly to increase accounting costs will be discussed at the Tuesday afternoon session by B. S. Rodey, chairman of the general accounting committee and associate controller of Consolidated Edison Co. of New York. He will point out means of offsetting the tendency toward higher costs.

A number of special groups will hold meetings at the convention apart from the general program. Three accounting meetings are planned for Monday, June 6th.

There will be a luncheon meeting at noon at which B. S. Rodey will preside, an all-day meeting of the Plant Accounting & Records Committee, with H. D. Anderson as Chairman, and a meeting of the Classification of Accounts Committee presided over by F. P. Dexter. Plans are also being considered for meetings of the Depreciation Committee, C. E. Kohlhepp, Chairman, the Customers' Relations, Commercial Accounting & Collections Committee, K. E. Boyle, Chairman, and the Purchasing, Stores and Transportation Committee, E. S. Brock, Chairman.

California Fair to Use New Light Sources

NEW LIGHT sources in the form of tubular fluorescent lamps will find their first large-scale outdoor application at California's 1939 International Exposition, according to W. P. Day, Vice President. The new lamps, announced by General Electric engineers utilize invisible sunrays imprisoned within their walls to bombard chemical powders to produce cool light sources that duplicate all the paste tints of the rainbow.

A. F. Dickerson, manager of General Electric's Illuminating Laboratory and Illuminating Engineer of the Golden Gate International Exposition, states that 2300 of these new tubes will be used in specially designed floodlights for providing the colored illumination of the walls of the Court of the Moon, Court of Reflection, Court of Seven Seas, Court of Flowers, and other locations.

Mr. Dickerson further states: "The possibilities of colored illumination in exterior use are greatly multiplied by the development of this new fluorescent tube. Efficiencies in terms of colored light have been stepped up in some cases as much as 100 to 1. Under this new light the walls of the courts will become luminous and iridescent in color shades and tones which heretofore have been artists' dreams that seemed beyond practical accomplishment. For the first time we are able to mix lights as we do paints and produce the theatrical results on large areas at a reasonable cost that have been limited in the past to the stage due to the expense."

Fluorescent powders compounded and specially heat-treated in the Company's Nela Park laboratories hold the secrets of the efficiency and color-producing qualities of the new light sources. Within their bulbs is a trace of mercury, a small amount of argon gas at low pressure, and a coating of fluorescent powders, selected and blended to produce the colored light desired. When current is applied, the argon serves as a "starter" and in a fraction of a second a feeble blue light with a large component of invisible ultra-violet radiation is generated inside the tube. This radiation strikes the fluorescent coating and is re-radiated in the visible range of the spectrum. Each powder has its own characteristic wave-band with which it responds to the ultra-violet, thus forming its own particular color of emitted light. San Francisco's Fair will become a milestone in lighting progress by pointing the way to the future widespread use of this new lamp in hundreds of applications where both utility and decoration are of permanent importance.

Fundamentals of the Turbine Generator

(Continued from page 385)

equivalent to supporting the weight of two standard automobiles on one square inch of surface (approximately 5000-6000 lb. per sq. in.). It is evident that the insulation of the rotor windings is the most difficult part of generator design and manufacture, and is the feature on which the life and operation of the machine mainly depend. It is a fact that many turbine-generators have been running for 10 or 20 years, and even longer, without repairs to the rotor windings. This is an unusual record and means that generator manufacturers have consistently used only the best materials available and have kept the standard of workmanship at a remarkably high level.

While only a few of the most important features of turbine driven generators could be covered in this article, it is obvious that there is more to buying such a machine than just saying "Give me a 5000 kw., 2400 v., 0.8 power factor generator". The generator is an intricate piece of apparatus, yet it is perfectly possible to specify reasonable characteristics without delving very deeply into the mysteries of generator design. When operating conditions are not known exactly, or where special characteristics are not required, specify a standard generator; when special features are necessary use the facts brought out in this article to help make the proper decision on type of generator required. In this way the manufacturer can be of most service to the prospective purchaser, and generators best suited for the conditions can be designed and built.

Flow Measurement by Pipe Bends

IN THE FLOW of liquid through a pipe bend, obviously the liquid at the outside of the bend is flowing faster than that at the inside, hence there is a difference in velocity head at the two points. This difference will be greater as the flow, hence the velocity increases; so that, if the difference in velocity heads between inside and outside of the bend be measured by a U tube or other means, as indicated in the drawing, it will give an indication of the velocity, therefore of the quantity of liquid flowing through the pipe.

Evidently the radius of curvature of the bend and the dimensions of the pipe, whether circular or rectangular, will affect the velocity-pressure differential between inside and outside of the bend. Also, to get consistent readings, the flow must be steady, at sufficient velocity to give a constant and measurable pressure difference, and free from eddies in the pipe.

Investigations by Wallace M. Lansford at University of Illinois Engineering Experiment Station and by Herbert Addison, recorded in Engineering of London, give the limiting conditions for satisfactory performance. While these investigations do not agree at all points they do give an indication of conditions required to have this method for flow measurement give dependable results.

If R = the mean radius of curvature of the bend, r the internal radius of the pipe or half the depth of a rectangular bend and b the breadth of rectangular bend, the limiting conditions for satisfactory use of the bend as a flow meter will be: as determined by Lansford, that R be at least three times r; that mean velocity through the elbow should be at least 2 ft. per sec.; that there be a length of straight pipe preceding the elbow equal to some 25 times the pipe diameter; that the ordinary commercial 90-deg. flanged pipe bend may be used successfully as a flow meter by this method; that for accurate results the apparatus should be calibrated by test and the ratio of flow to pressure difference determined.

Addison sets limiting values as: R ÷ r at least 3; least mean velocity in bend 4 ft. per sec.; straight approach of 60 times pipe radius was used; results were more consistent for a reversed curvature discharge than for a continuous curvature discharge of two 90-deg. elbows but differential pressure was greater, and in both cases greater than for a single 90-deg. bend.

Both sets of experiments show that the coefficient of discharge increases with pipe diameter. Threaded pipe bends are not desirable because of the change in inside diameter. Any valve to control discharge should be located at least 10 pipe diameters down stream from the elbow.

In case an elbow cannot be calibrated, Mr. Lansford states that a value for discharge coefficient can be chosen, from his experimental values, with error of less than 10 per cent. Pressure difference in feet head of water is: $h = (C\ V^2) \div (2g)$ where C is coefficient of discharge,

V is mean velocity through the elbow, in ft. per second

g is the acceleration due to gravity. = 32.16

Then $V = \sqrt{64.32\ h \div C}$

Since $Q = A\ V$

where Q is cu. ft. per sec.

A is area of pipe cross section in sq. ft.

V is mean velocity in ft. per sec.

$Q = A \sqrt{64.32\ h \div C}$

or the cu. ft. per min.,

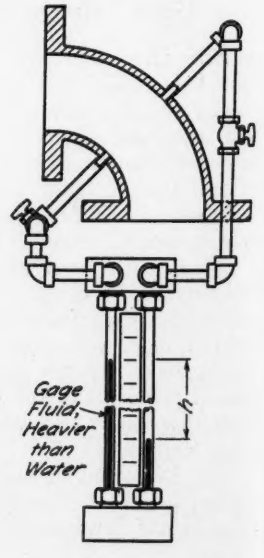
$Qm = 60\ A \sqrt{64.32\ h \div C}$

Values of C as given by Lansford for commercial elbows are, $C = 64.32\ h \div V^2$, which should be checked by calibration. As found from tests, values are given in the table.

AVERAGE COEFFICIENTS FOR ELBOW METER FLOW
Velocity in pipe, ft. per sec.

Kind of Elbow	2		3		4		6		8		10		12		14	
	h	C	h	C	h	C	h	C	h	C	h	C	h	C	h	C
1 in.	0.085	1.41	0.19	1.39	0.33	1.37	0.76	1.36	1.4	1.32	2.1	1.32	2.9	1.32	4.8	1.32
2 in.	.....	1.5	0.21	1.5	0.37	1.50	0.85	1.5	1.5	1.5	2.4	1.5	3.1	1.5	5.0	1.5
4 in.	0.10	1.49	0.22	1.49	0.38	1.49	0.81	1.49	1.4	1.49	2.6	1.49	3.4	1.49	4.7	1.49
8 in.	0.14	1.97	0.30	1.95	0.54	1.95	1.15	1.95	2.1	1.95	3.1	1.95	4.5	1.95	6.5	1.95

By choosing C from the values given in the table according to pipe size and velocity of flow and checking values of h, C and Q from computation and from test at a few velocities, it should be possible to get results within at least 5 per cent accurate and the convenience of the method makes it useful for approximate measurements of flow, especially for comparison of flows under varying conditions.

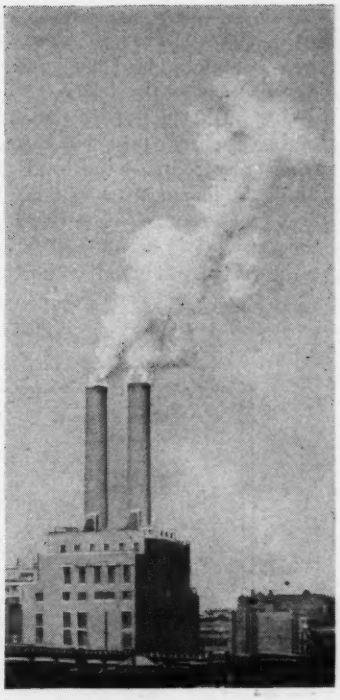


Section through 90 deg. elbow showing method of making connections for the measurement of flow

Flue Gases Laundered to Prevent Air Pollution

Wet treatment used to remove dust, soot and sulfurous gases offers economic possibilities

By DR. R. V. KLEINSCHMIDT
Physicist and Research Engineer,
Arthur D. Little, Inc., Cambridge, Mass.



Winter appearance of stack gases that are clear in summer

THE RECENT publication of several papers dealing with various aspects of the problem of sulfur removal from flue gases makes it desirable to summarize the present status of the entire problem from a practical angle, in order that the significance of the new contributions may be properly evaluated as they affect power plant design and operation.

Forty years ago, industrial wastes were dumped more or less indiscriminately into the water or air as convenience dictated. Today, many jurisdictions have rigid restrictions on pollution of streams and on the discharge of excessive quantities of smoke, dust and fly ash into the air. England has been a leader in this movement and specifications for the Swansea and Fulham power plants in 1935 called for 96 per cent elimination of both dust and SO_2. (1)

The large tonnage of SO_2 now discharged into the air from power plant stacks, especially in the Middle West where high sulfur coals are burned, creates a serious corrosion problem in industrial communities and is inimical to plant life over a wide area. Professor Parr(2) estimated in 1928 that 20 million tons of SO_2 were discharged into the air per year in this country. Although no actual hazard to human health has been proved, the breathing of sulfurous fumes is certainly distasteful to everyone.

Engineers have long recognized the desirability of reducing the discharge of sulfur into the atmosphere, and large boiler plant operators, both in this country and abroad, have sponsored extensive experiments, looking toward the development of processes for this purpose. Until recently, however, the equipment phase of flue gas cleaning has been far from satisfactory.

(1) Pearson, et al. Inst. of Elect. Engrs. and Institute of Fuels, Jan. 17, 1935.
(2) Parr. Ind. & Eng. Chem. 20, 454, (1928) quoted by Johnstone, Third Int. Conf. on Bituminous Coal, Carnegie Inst. of Tech., Nov. 16-21, 1931.

Problems Involved in Flue Gas Cleaning

In view of the probability that in the not far distant future, removal of sulfur will be desirable or even mandatory, any form of flue gas cleaning equipment should be considered from the points of view of both dust removal and removal of sulfur.

The important considerations in selecting flue gas cleaning equipment are:

1. Adequate efficiency in cleaning the gas, under all load conditions.
2. Low consumption of energy.
3. Simple equipment whose operation is readily understood by the operating force.
4. Low weight and volume of equipment, since such equipment is often best located at a high level in the power plant.
5. Discharge of waste material in a form suitable for disposal.

It is a direct corollary of the above conditions, that removal of dust and sulfur gases should be accomplished at one and the same time, since a two-stage process would increase weight and cost materially.

The efficiency of cleaning is usually stated in terms of percentage by weight of dust or sulfur removed. This basis is, however, often misleading. The percentage removal efficiency may vary considerably with both the gas velocity and the dust loading. Thus a low efficiency during a period of heavy dust loading, cannot be offset by high efficiency during periods of light dust loading. Moreover, the methods of sampling must be carefully controlled to prevent improper weighting of results with respect to fine and coarse particles of dust, and to a lesser extent, loss of sulfur gases.

The consumption of energy cannot be computed directly from the pressure drop in the cleaning equip-

ment in devices such as washers which cool the gases. The energy required by induced draft fans working on a given weight of cool gas with a given pressure difference across the fan is very much less than when working on hot gases of greatly increased volume. In certain types of equipment discussed below, this effect has actually reduced the total power required so that a credit is shown on this item. For example, gases at 500 deg. F. require 35 per cent more power than the same gases after scrubbing with water, even allowing for the added water vapor discharged.

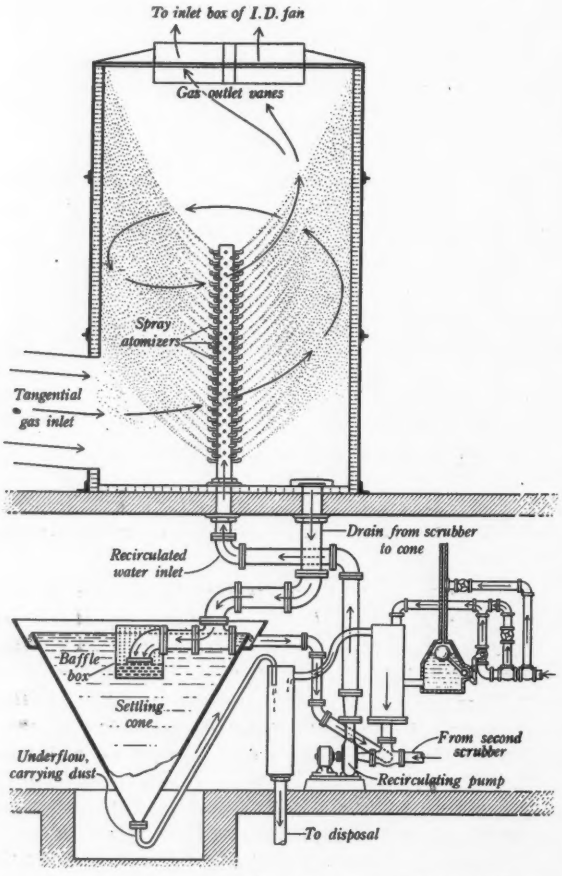


Fig. 1. Diagrammatic sketch of flue gas scrubbing system

The form in which waste materials are best disposed of varies with local conditions, but it may be said that except where a definite use for dry material exists, fly ash is best handled in a damp condition.

The disposal of sulfur gases, mainly sulfur dioxide, is an extremely interesting problem. Except in the immediate vicinity of salt water, it is not possible to throw the stuff away. On the other hand, sulfur dioxide is a step in one of the basic chemical processes, the manufacture of sulfuric acid, and as such is used to the extent of thousands of tons per day. It also has a number of other uses, as in sulfite pulp manufacture, plastics, bleaching, and refrigeration. During the year 1936, over two million tons of sulfur were produced in the United States. The recovery and marketing of sulfur in some form, therefore, becomes practically a necessity in connection with its removal from flue gases.

Types of Equipment

It is not the purpose of this paper to discuss the various types of equipment that have been proposed for flue gas cleaning, except to indicate the major types in the field of highly efficient cleaning.

These include electrical precipitators, several forms of supercyclones, and various types of washers. Of these, the last are particularly adapted to simultaneous dust and sulfur removal.

The removal of dust by washing with water is old and well known in principle. Not enough attention, however, has been paid to the factors which produce high efficiency in this type of equipment. For removal of SO_2, some form of liquid contact device is required by most of the processes which have been developed or proposed. Theoretically, at least, a properly handled spray of liquid particles should form an ideal method of producing intimate gas-liquid contact. Unfortunately, very little careful analysis of this problem had been made until a few years ago. The removal of spray from the gases is a serious problem in the older types of washers and limits the fineness of atomization to relatively large drops which will fall by gravity, or be readily thrown out by baffles or eliminator plates. The surface of liquid exposed is, therefore, low and the water quantities used are large, while the dust removal is poor in the finer sizes unless excessive quantities of water are used.

In the case of flue gases, the water used becomes acid and strongly corrosive, so that eliminator plates are difficult to protect from corrosion. When using alkaline solutions for SO_2 removal, complete elimination of entrainment is especially important, to avoid loss of chemicals. It thus became apparent that a suitable combination of the liquid spray washer using very fine atomization with centrifugal separation could be developed to produce an exceptionally efficient flue gas scrubber. The Pease-Anthony gas scrubber combines effectively the desired qualities. Originally developed for removing fine dust, it became apparent that the same features which produced high efficiency in dust removal would also tend toward high efficiency of gas absorption. The tests reported by Johnstone and Kleinschmidt[3] fully substantiate this prediction, and indicate on a full plant scale that this equipment is suitable for a combined sulfur and dust removal process. A brief description of the equipment is therefore of interest.[4]

The scrubber proper consists of a vertical cylindrical chamber, having a tangential gas inlet at the bottom and a central discharge collar at the top. Along the lower portion of the axis of the cylinder spray nozzles are located, which discharge a fine spray of water or other washing fluid into the center of the rotating mass of gas. This spray, most of which is too fine to be carried by its initial velocity across the gas stream to the wall of the scrubber, is picked up by the whirling cylinder of gas and carried by centrifugal action across the gas, being finally thrown against the

(3) Trans. Am. Inst. Chem. Engrs. April, 1938.
(4) Ref: Engle. Transactions. A.S.M.E. Vol. 59, No. 5. P. 359-360.

wall, where it flows down to a collecting basin at the bottom. It then flows to suitable settling cones to remove the suspended solids, and is recirculated with fresh makeup water, to the sprays.

Although the design of this scrubber is apparently very simple, the action involved is rather complex. The fine atomization of the water results in a very large surface exposed to the action of the gases, and the fine water particles are forced positively across the gas stream by centrifugal force, giving a relatively long time of contact.

The action in the scrubber is to be distinguished from the action of a cyclone in that the sprays are arranged and operated so as to produce a spray of a definite fineness, and the centrifugal action is properly adjusted to throw out these particles. The impact of the liquid particles with the dust particles carries the latter to the walls of the chamber. In so doing, the water particles on the average sweep the entire volume of the flue gases several times.

Several features of this equipment should be noted. The thoroughness of contact is indicated by the fact that the gases are brought to equilibrium saturation temperature. The scrubbing liquid is settled sufficiently to permit continuous recirculation of the liquid without serious trouble in either pumps or nozzles. When recirculating ordinary water, the scrubbing liquid becomes weakly acid, containing approximately 0.2 per cent of total acid, calculated as H_2SO_4, and there are present traces of HNO_3 and substantial amounts of SO_2, HCl, and CO_2. The reducing action of the SO_2 renders the liquid highly corrosive to all common metals, and non-metallic linings are used throughout the liquid cycle, mainly rubber and resins. Acid-proof brick is used to line the scrubber. Naturally, this corrosion problem increases the initial cost of the installation and involves a certain amount of periodic maintenance. The use of an alkaline scrubbing fluid with removal of the SO_2 as absorbed will permit a considerable reduction in first cost. It is quite probable that the investment in equipment of this nature for the removal of dust and SO_2 together and the recovery of the latter in salable form, will not exceed the cost of electrical precipitators.

Economic Aspects of SO_2 Removal

The removal of fly ash and other dust will probably never be regarded as directly economical, in spite of savings in power and in fan maintenance. The removal of SO_2, however, may prove to be not only economical but actually profitable enough to carry a considerable portion of the burden of dust removal as well. It is, of course, necessary to remove the dust either before or during the SO_2 absorption. The overall picture requires some careful examination. It is generally supposed that any extensive move to recover SO_2 from flue gases would result in such large production as to glut the market and bring about ruinous prices. There is some foundation for this belief. The total sulfur discharged daily by coal burning boilers in the United States is of the order of 27,000 tons, while the average consumption of sulfur is of the order of 6000 tons per day. But the recovery and handling of SO_2 is a chemical process which few power plant operators would care to undertake unless they had their own uses for the material. It seems therefore quite probable that active development along these lines should properly have the backing of one of the larger chemical companies, who would at least handle the marketing of the product, and might also operate the recovery plant.

The economics of SO_2 removal depend very largely on local conditions. There are a number of forms in which the sulfur can be finally recovered for sale, and any specific application of the recovery equipment should be studied with some care in relation to surrounding markets. The following possible processes are suggested for consideration:

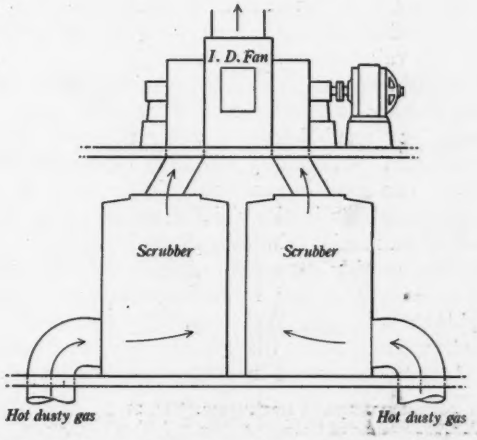


Fig. 2. Relative locations of scrubbers and induced draft fan

1. Sulfuric Acid—By far the largest single use of SO_2 or sulfur is in the manufacture of sulfuric acid. If possible, therefore, the direct production of sulfuric acid from the flue gases might seem desirable. Such processes have been studied by Johnstone[5] and others. It is well known that iron and other related metals catalyze the oxidation of SO_2 in aqueous solution to sulfuric acid. Concentrations of the order of 3 to 5 per cent can be produced directly in the scrubber by addition of a small amount of scrap iron to the scrubbing water. The first traces of SO_2 absorbed rapidly attack and dissolve the iron which then catalyzes the oxidation of SO_2 to SO_3. The addition of a preconcentration step in the form of a small spray chamber in which the hot gases are practically saturated permits the building up of almost any desired concentration of acid. This acid is contaminated by the iron salts introduced, but is satisfactory for pickling iron and steel, for superphosphate manufacture, and for a number of other large scale uses.

The disadvantages of this process are the relatively slow rate of absorption of SO_2 in the acid liquor, the extreme corrosiveness of the liquid to be handled, the low quality of the acid produced, which on account of its dilute condition must be absorbed by a local market, and the problem of disposing of the ash when saturated with acid water.

2. Sulfites and sulfates—Many of the disadvantages of direct production of acid are eliminated by

(5) Johnstone. Ind. & Eng. Chem. Vol. 23, P. 559, May, 1931.

the production of salts of either sulfurous or sulfuric acid. Among the possibilities are sodium sulfate, ammonium sulfate[6], magnesium sulfate, calcium sulphate[7], ferrous sulfate and zinc sulfate, and the corresponding sulfites and bisulfites. Several of the sulfites, notably calcium and zinc sulfites, are highly insoluble and could be precipitated in a fairly pure condition by a two-stage process. Unfortunately all of the above salts are either very cheap by-products or natural minerals, or are very limited in their uses. They also require, in many cases, vaporation and crystallization processes to put them in a salable form. They must be regarded mainly as methods of disposing of small quantities of sulfur, the recovery of which is not justified, and which must be eliminated because of some special local conditions. In this connection, ammonium sulfate offers the best prospect for recovery of the full value of the alkali used.

A study has been made of a specific case in which serious damage to nearby steel work could have been prevented by scrubbing with water to which enough ammonia was continuously added to render the water alkaline. The resulting ammonia liquor could be sold to fertilizer plants in the vicinity, at the value of the contained ammonia. The overall saving due to elimination of corrosion appeared to justify the installation.

3. Liquid SO_2—For large installations, it seems probable that recovery in the form of compressed anhydrous liquid SO_2, offers the best prospect for profitable sale of the SO_2 removed from the flue gases.[8] In this connection, one must not be misled by the quotation on "refrigeration grade" SO_2 which is highly purified by an expensive process. Liquid SO_2, as recovered from flue gases, can be sold only in competition with sulfur, at approximately one-half the value per ton of elemental sulfur. Even at these prices, however, there is reason to believe that all operating costs can be covered and that some return can be expected on the investment. Further development may be expected in the near future.

4. Elemental Sulfur—An interesting paper on the theoretical aspects of this process has been presented by Lepsoe[9]. The economics does not look attractive except in special cases.

(6) Johnstone. Ind. & Eng. Chem. Vol. 27, P. 587 (1935).
(7) Pearson et al. Inst. of Elect. Engrs. and Inst. of Fuels. Jan. 17, 1935.
(8) Johnstone, Read and Blankmeyer. Ind. & Eng. Chem. Vol. 30, P. 101 (1938).

Conclusion

Recent developments in the chemical phases of sulfur recovery from flue gas and the impending pressure to reduce atmospheric pollution in large industrial centers point toward compulsory removal of excessive quantities of sulfur dioxide from flue gases, particularly in regions burning high sulfur coals, at some future time. The successful development and demonstration of a wet type flue gas scrubber of high efficiency, both for dust removal and absorption of SO_2, makes it advisable to consider this type of equipment in preference to types which are not suitable for gas absorption, even where the removal of SO_2 is not contemplated at the outset. Under favorable conditions, recovery of sulfur should be possible at practically no net cost to the power plant.

(9) Lepsoe, Ind. & Eng. Chm. Vol. 30, P. 92 (1938).

Does Preheated Air Decrease Flue Gas Temperatures?

Backed by a wide experience in combustion engineering, J. R. Darnell brought this question up in an article on p. 142 of the February issue. He pointed out that opinions differ among engineers, but came to the conclusion that if full advantage is taken of preheat, the flue gas temperature will be lowered. Adolf Johnson analyzes the problem from a theoretical angle and comes to the same general conclusion. The higher temperature exponents seem to have been driven to cover. Perhaps some operating data would show whether practice agrees with theory, or, whether there are other factors involved which affect the reliability of theoretical deductions.

By ADOLF JOHNSON

THIS QUESTION PRESENTS an interesting problem which can be solved, theoretically at least, by tracing the gas flow from initial combustion to the final temperature leaving the boiler. A careful valuation of the pertinent factors influencing furnace temperature and heat transfer rates throughout the unit will show that the application of pre-heated air does reduce the boiler exit gas temperature.

Take first the simple case of a water tube boiler, with no superheater, set over a refractory furnace. The furnace can be fired with any type of fuel and the CO_2 can be assumed as constant from furnace to boiler exit, since, for practical purposes, infiltration can be assumed as a variable unaffected by the use of pre-heated air.

To produce a certain quantity of steam, the furnace requires a certain input in B.t.u. per hour. This input depends on the thermal efficiency of the unit, which in turn depends on the exit gas temperature, radiation loss, carbon loss and unaccounted for losses. The input

is supplied by the fuel and the heat in the air required for combustion. If the air is cold, the total input comes from the fuel. If the air is pre-heated some of the heat input comes from the heat in the air so less fuel is required to make up the total input requirements of the boiler.

Pre-heated air then reduces the required fuel input, and so proportionally reduces the total amount of air required to burn the necessary fuel. It can therefore be stated that the weight of the combustion gases to the boiler is reduced in proportion to the reduction of the fuel weight. Contrary to one of the quotations in J. R. Darnell's article, the reduction in gas weight effected by the addition of pre-heated air is appreciable. In fact, it is by this reduction in gas weight that it can be proved the boiler exit gas temperature drops for each increase in air temperature to the furnace.

Gas Weight Calculation

An example will clearly illustrate that this reduction in gas weight is appreciable. Assume that the required furnace input is 50,000,000 B.t.u. per hr., and that the gas weight is 12 lb. per lb. of coal, the latter having a heat value of 13,000 B.t.u. per lb. From burning sufficient coal to give the required input, the weight of gases in pounds per hour is:

$$(50{,}000{,}000 \div 13{,}000) \times 12 = 46{,}000$$

This is the weight when cold air is introduced for combustion. Now assume that the air enters the furnace at 350 deg. F. The pounds of air required per pound of fuel is, of course, the gas weight minus the fuel weight, or 11 lb. of air per lb. of fuel. The air weight in pounds per hour, therefore, is:

$$(50{,}000{,}000 \div 13{,}000) \times 11 = 42{,}200$$

The heat input in B.t.u. per hour supplied by the hot air, assuming a specific heat of 0.24 for air, is:

$$42{,}200 \times (350\text{—}80) \times 0.24 = 2{,}740{,}000$$

This leaves, in B.t.u. per hour, to be furnished by the fuel:

$$50{,}000{,}000 - 2{,}740{,}000 \text{ or } 47{,}260{,}000.$$

The weight of combustion gases, in pounds per hour, with pre-heated air is therefore reduced to:

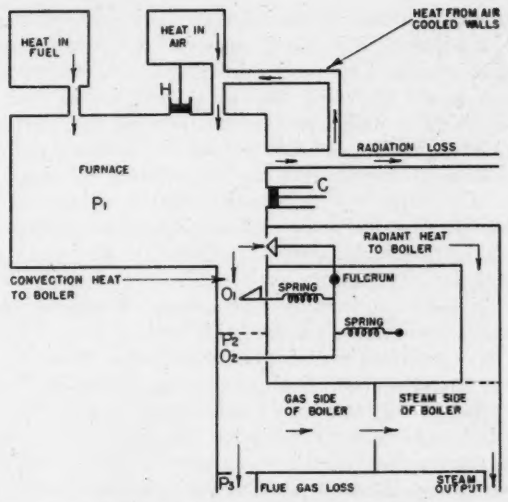
$$(47{,}260{,}000 \div 13{,}000) \times 12 = 43{,}600$$

This is about a five percent reduction in gas weight, sufficient to effect the boiler exit gas temperature. In the above example, the air weight was based on total input of 50,000,000 B.t.u. per hr. If the air weight were corrected for the lower input of 47,260,000, it would produce a negligible increase in the gas weight, for pre-heated air as calculated above.

Furnace Temperature

In opposition to quotations in Mr. Darnell's article, it can be proved that within the comparatively narrow limits of variation in gas weight obtained with and without pre-heated air, the furnace exit temperature is not appreciably changed. However, the theoretical or adiabatic temperature is increased with the use of pre-heated air. Using the values of heat input and gas weights in the previous examples we see that the B.t.u. per pound of gas in the furnace at the instant of ignition, for cold air, is:

$$50{,}000{,}000 \div 46{,}000 = 1087$$



Hydraulic analogy illustrating the effect of preheated air on furnace and boiler exit temperature. Water pressures are analogous to gas temperatures and water flow is analogous to heat flow

This is equivalent to an adiabatic temperature of approximately 3400 deg. F., for the exact value varies, of course, with the per cent of moisture in the flue gas.

For pre-heated air, the B.t.u. per pound of gas is:

$$50{,}000{,}000 \div 43{,}600 = 1145$$

which is equivalent to approximately 3580 deg. F. adiabatic temperature.

Assume 200 sq. ft. of boiler heating surface facing the furnace radiation and a heat absorption rate of 30 B.t.u. per sq. ft. per deg. F. per hr. by this cold surface. For 150 lb. operating pressure the log mean temperature difference between cold surface temperature and gas temperature is:

$$\begin{array}{rr} T_1 = 3400 & T_2 = 2500 \\ t_s = \ 365 & t_s = \ 365 \\ \hline 3035 & 2135 \\ 2135 & \\ \hline \end{array}$$

$$900 \div \log_e \frac{3035}{2135}$$

$$= 900 \div 0.35 = 2560$$

Radiant heat absorption by Cold Surfaces, in B.t.u. per lb. of gas.

$$(2560 \times 30 \times 200) \div 46{,}000 = 333 \text{ B.t.u./lb. gas.}$$

In the above calculation: T_1 is the adiabatic temperature in deg. F.; T_2 is the assumed furnace exit temperature in deg. F.; t_s is the saturated steam or cold surface temperature in deg. F.

The B.t.u. per lb. of gas leaving the furnace is then the B.t.u. entering furnace less the B.t.u. absorbed by the cold surface in the furnace, or:

$$1087 - 333 = 754$$

This is approximately equivalent to a 2500 deg. F. furnace exist gas temperature.

Following the same procedure for pre-heated air, the mean temperature difference is found to be 2630 deg. F. The Stefan-Boltzman Law states that the radiation transfer rate is proportional to the fourth power

of the mean temperature difference between the hot and cold mediums. This is only true for two parallel black bodies separated by non-luminous space. Ordinary furnaces depart from this theoretical condition in that the space is filled with incandescent burning fuel particles each of which is a radiator of heat. In addition to these luminous particles, there is re-radiation of the heat from the refractory walls to the cold absorbing surface. These factors and many others depending on type of fuel, distribution of cold surface, and dimensional characteristics of the furnace complicate the analysis of the furnace temperature and a complete discussion of these is beyond the scope of this article.

It is sufficient to state that the effect of these departures from the theoretical premises of the Stefan-Boltzman Law is to introduce a species of "inertia" which tends to maintain the radiation transfer rate constant. For the purposes of this example we can very roughly assume that the transfer rate varies not as the fourth power but as the square of the mean temperature difference. We shall therefore increase the assumed radiant transfer rate of 30 for cold air in this proportion, or, to 31.9 for the hot air. The heat transfer to the cold surface, B.t.u. per lb. of gas is then:

$$(2630 \times 31.19 \times 200) \div 43{,}600 = 385$$

The heat leaving the furnace is then 1144 — 385 or 759 B.t.u. per lb. of gas or approximately equivalent to 2520 deg. F.

Radiant Heat Absorbed in the Furnace

Generalizing on these results we can say that the addition of pre-heated air to the furnace has little effect on the furnace exit temperature simply because the total radiation absorption is dependent on temperature and therefore, regardless of gas weight (within the limits of variation which can be effected by addition of pre-heated air), the total absorption by the cold surface facing the boiler is approximately constant. Since the total absorption is constant the B.t.u. absorbed per pound of gas increases with a decrease in gas weight. It was shown that gas weight does decrease with pre-heated air and therefore the absorption per pound of gas increases. The increase in absoption per pound of gas caused by the pre-heated air, cancels in effect the increase in B.t.u. per pound of gas due to the additional heat supplied by pre-heated air, resulting in a furnace exit heat per pound of combustion gases approximately equal to that when cold air is used.

Boiler Heating Surface

We now enter the boiler heating surface and will endeavor to show that the gas temperature gradient through the boiler will be steeper when pre-heated air is used. The fundamental equation for heat transfer from a varying temperature medium, such as furnace combustion gases, to a constant temperature medium, such as the mixture of steam and moisture in boiler tubes, is:

$$(T_1 - t_s) \times e^{-b} = (T_2 - t_s) \qquad \text{Eq. 1}$$

where:

T_1 is the entrance gas temperature in deg. F.
T_2 is the exit gas temperature in deg. F.
t_s is the saturated steam or tube temperature for clean boiler surfaces in deg. F.
e is the 2.718 or base of natural logarithm system.
U is the heat transfer rate in B.t.u. per sq. ft. per deg. F. per hr.
S is the heating surface of boiler in sq. ft.
W_g is the weight of combustion gases in lb. per hr.
c_g is the specific heat of combustion gases in B.t.u. per deg. F.
b is $U \times S \div (W_g \times c_g)$.

To simplify the equation it is advisable to reduce as many factors as possible to constants, leaving only those which are variable in the specific problem at hand. The following may be considered as practically constant within the limits of variation imposed by addition of pre-heated air:

T_1 the furnace exit temperature (previously established)
T_s the saturated steam temperature
S the boiler heating surface
c_g the specific heat. As the exit temperature does not vary sufficiently to effect the average specific heat of the gas from the boiler entrance to the exit

Re-writing the equation and lumping constants into one figure and transposing and letting a equal K U $\div$ W_g

$$T_2 = Ke^{-a} - k \qquad \text{Eq. 2}$$

which indicates that T_2, the boiler exit gas temperature depends entirely on the ratio of U to W_g.

First, consider the transfer rate U, which is the sum of the radiation transfer rate, U_r, and, the convection transfer rate U_c, or:

$$U = U_r + U_c \qquad \text{Eq. 3}$$

U_r is dependent on log mean temperature difference between the average gas temperature and the steam temperature. The exit gas temperature of the boiler is so much lower than the entrance gas temperature that the comparatively small change in boiler exit temperature between pre-heated air firing and cold air firing will not vary the log mean temperature difference between gas and tube enough to cause an appreciable change in radiation transfer rate. We may therefore assume that U_r is also a constant within the limits of the variations imposed by the difference in the air temperatures to the furnace. So the exit gas temperature, where K represents the constant radiation transfer rate, depends on the ratio of $(U_c + K)$ to W_g.

Reference of texts on heat transfer of gases over a row or rows of tubes will show that the convection transfer rate varies as some power, less than unity, of the velocity of the gas through the free flow area between the tubes. An average value is about the 2/3 power of the velocity of the gas. The velocity is practically proportional to the gas weight since the temperatures throughout the boiler for either cold or pre-heated air do not differ considerably. Therefore, the convection transfer rate is proportional to the gas weight ratio to the 2/3 power.

The addition of pre-heated air reduces the gas weight through the boiler. When the gas weight is

reduced the value of U_c decreases only as the 2/3 power of the ratio of the final and initial gas weight. Thus:

$$\frac{U_c\left(\frac{W_{gh}}{W_{gc}}\right)^{2/3} + K}{\left(\frac{W_{gh}}{W_{gc}}\right) \times W_{gc}} \qquad (4)$$

Where:

W_{gh} = weight of gas with pre-heated air.
W_{gc} = weight of gas with cold air.

In other words U_c decreases slower than W_g and the ratio $(U_c + K)$ to W_g, or, U to W_g *increases* with a decrease in gas weight. If $U \div W_g$ increases, then e^{-a} decreases since e^{-x} is equal to the reciprocal of e^x. As e^{-a} decreases, T_2 decreases as shown by Eq. 2.

This all boils down to the fact that for a constant heating surface, a reduction in gas velocity reduces the transfer rate per square foot of heating surface, but the reduction in velocity allows the gas time to give up more of its heat per pound of gas before it leaves the boiler.

An increase in CO_2 will result in lower boiler exit gas temperatures as well. If the CO_2 or excess air is varied so that the gas weight does not vary beyond the limits that are obtained with cold and pre-heated air, there will also be no appreciable variation in furnace temperature. If, however, the excess air is decreased from say 35 to 20 per cent, there will be appreciable increase in furnace exit temperature because the radiation transfer rate will not increase sufficiently to maintain approximately the same furnace exit temperature as obtained with a higher excess air or lower CO_2.

Air Cooled Walls

The only case where pre-heated air will not decrease boiler exit temperature is where air cooled walls are used as the air pre-heating medium. In this case, the heat required to raise the air temperature is taken from the input to the furnace by radiation loss through the refractory walls. It does not supplement the input, it takes heat from it, then returns the heat to the furnace by means of the heated air entering the burner or stoker. The net reduction in fuel burned is zero and the only saving is smaller radiation loss in the furnace than would be encountered with solid refractory walls, and, some increase in combustion efficiency. There would be no change in furnace temperature, no reduction in gas weight and therefore no decrease in boiler exit gas temperature.

Figure 1 is a hydraulic analogy illustrating the variations in furnace and boiler exit temperatures as affected by pre-heated air, cold air, air cooled walls and change in CO_2. Water pressures represent temperature and water flow represents heat flow. If pre-heated air is tapped to the furnace less heat is tapped from the fuel reservoir so that the total heat flow to the furnace is constant. However, the piston H increases the pressure P_1 in the furnace, which is equivalent to an increased adiabatic temperature. The increased pressure opens the spring controlled valve increasing the radiant heat flow to the boiler at the same time restricting convection flow area O_1 to boiler to maintain almost the same pressure P_2 leaving the furnace, whether cold or pre-heated air is used. Since more radiant heat flows to the boiler when pre-heated air is used, there is smaller convection heat flow to the boiler and the reduction of opening O_2 represents the ratio of U to W_g increasing, causing a reduction in P_3 or exit gas temperature.

Compressing piston C represents an increase in CO_2 and has the same effect as the addition of pre-heated air unless the pressure or CO_2 is increased beyond the limits that are ordinarily obtained by increasing the air entrance temperature. The diagram illustrates that too great an increase of CO_2 limits the radiant heat flow to the boiler forcing more convection heat to enter O_1, increasing this opening and thus increasing P_2 or the furnace exit temperature. Pre-heated air from air cooled walls has no effect on the radiant and convection heat flow, as illustrated in the diagram.

It is my opinion that an increase of CO_2 with the use of pre-heated air is not good practice since the small gain in efficiency does not warrant the higher furnace wall and boiler tube maintenance that may be encountered due to increased furnace temperatures. I agree with Mr. Darnell that the use of pre-heated air does not mean that less attention can be paid to the operation of the furnace and firing equipment. This seems true, because, although the temperature leaving the furnace is not appreciably altered, the temperature in the vicinity of the burner and stoker are actually higher than with cold air. This means, of course, that the operator must keep a weather eye on this section of the furnace so as not to allow excessive slag accumulation or spalling on the furnace walls.

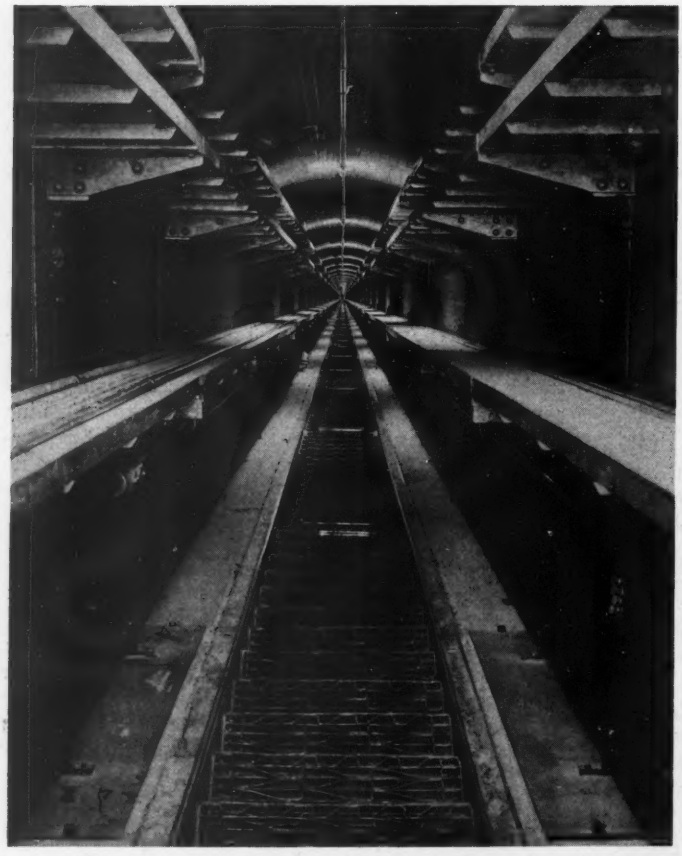
Diesel Engine Wear

While discussing the effects of lubrication on engine wear before the Annual Tractor Meeting of the S. A. E., C. M. Larson, chief consulting engineer of the Sinclair Refining Co., said:

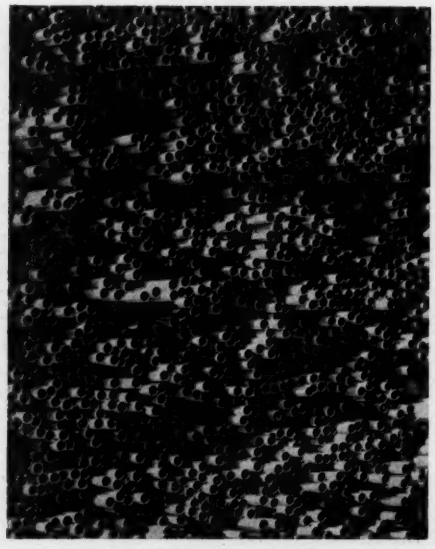
"Results of most of the comparative wear test research in recent years has shown that, in general, the compression-ignition engine has cylinder and ring wear characteristics about 85 per cent greater than the corresponding gasoline engine. The average cylinder wear found by investigation and reported in the literature since 1930 was 0.0018 in. per 1000 hr. for gasoline engines, and 0.0035 in. per 1000 hr. for compression-ignition or Diesel engines when using straight mineral oils. In the case of the Caterpillar engine, this wear has been reduced from .0025/.004 to 0.0010 in. and less per 1000 hr. of operation by the use of certain addition agents.

"Other tractor Diesel engines have tested out such addition agent alloyed lubricating oils, reporting compression maintained and power somewhat higher than normal for 625 hr. periods. The rings were free, pistons bright and oil drain holes in rings open. The spark ignition oil engine operators have adopted alloyed oils to excellent advantage, but these alloyed oils are limited to Babbitt bearings because they are corrosive to other types."

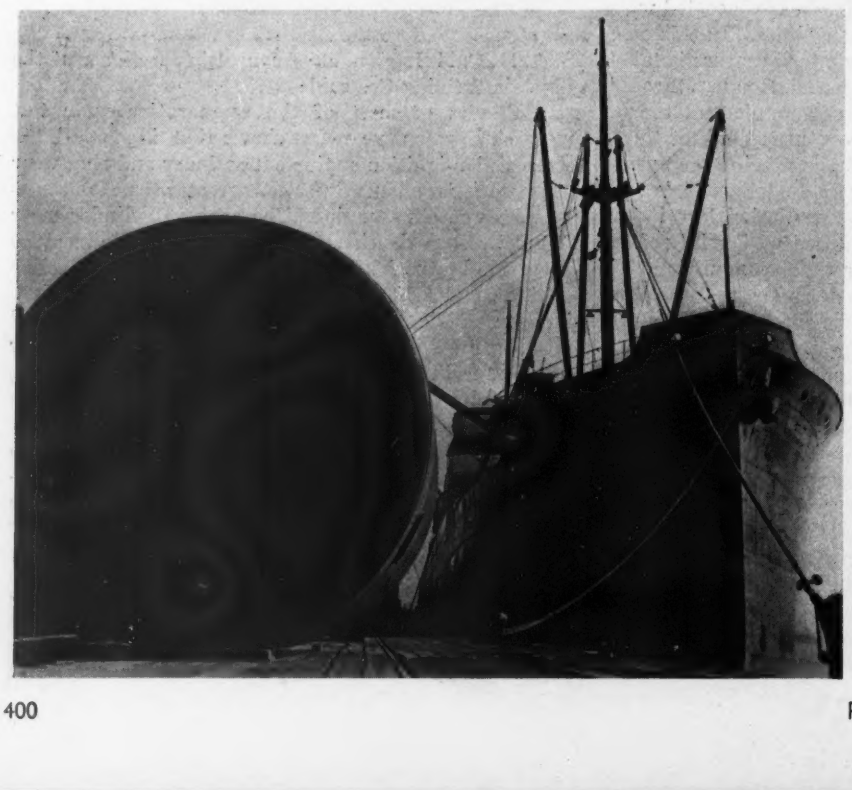
PICTURES



Watch your step! If you trip at the top of this stairway you may fall 700 feet and land in the powerhouse at Boulder Dam. The grillwork steps lead from the switching station at the top of the Nevada Canyon, through this inclined tunnel which carries circuit cables from the powerhouse. A freight car operates on tracks over the stairway.
Photo furnished by the Bureau of Reclamation

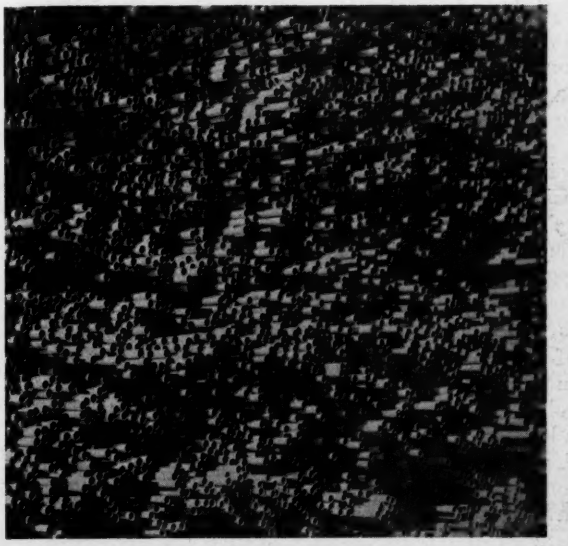


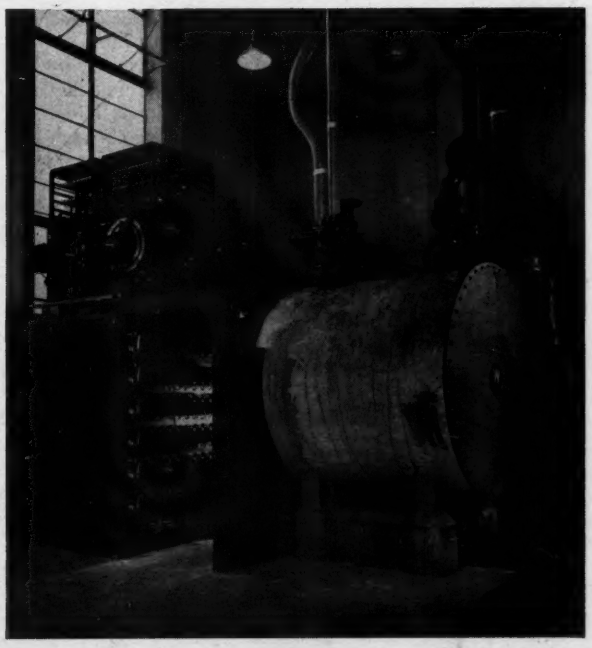
In piles such as this, 800 miles of 1-in. steel pipe is kept in stock at Grand Coulee Dam to be used in the system which refrigerates the concrete. In all 2000 miles of pipe will be needed. It is built into the dam in closed circuits into which cold water is pumped at one end and warm water drawn off at the other end. Thirty thousand tons of coal would generate no more heat than will be liberated in the curing of the 11,250,000 cu. yds. of concrete in the dam



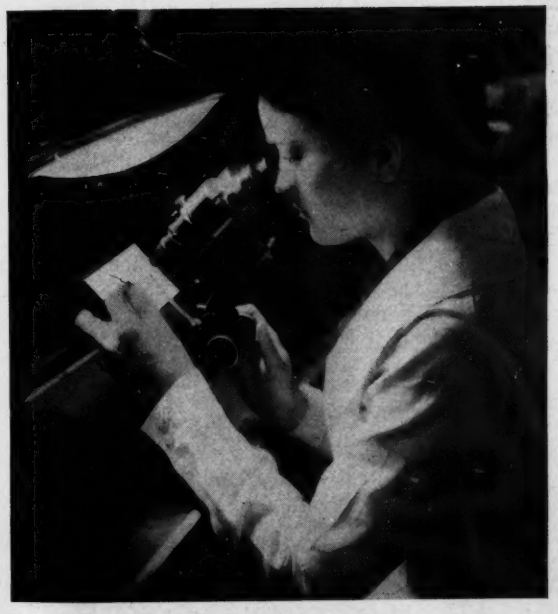
Following the sale to the Rainier Paper Co. for its new Fernandina, Florida, plant of the largest sea water regenerating zeolite water softening plant in the world, the Permutit Co. chartered a ship to make delivery. The plant consists of specially constructed 14 ft. diameter zeolite softeners and 8 ft. diameter by 20 ft. long filters. It will handle 10,000,000 gal. of water per day and will produce a finished process and boiler feed water. It is fully automatic in operation. The view at the left shows the shipment being made. It involves some 800 tons—a hefty bit of water conditioning. The tank, we have a sneaking suspicion, is not quite as large in comparison with the ship as it seems in this picture and yet we seem to remember an old saying that the camera never lies. What do you think?

# of Engineering Interest





Unique among the methods provided for dissipating excess electrical energy generated by engines undergoing tests at the Detroit Diesel Engine Division Plant and in the new Diesel Test Laboratory of the General Motors is this electric boiler, which will be used for heating purposes during the winter months as a water rheostat in summer. It contains 186 heating elements capable of dissipating nearly 2800 engine horsepower



(Above) This comely young woman in her gleaming-white starched uniform, peering through the microscope might be a bacteriologist on the trail of some deadly germ. Actually, she is an inspector in the General Electric plant at Lynn examining an armature pivot of a G. E. instrument. Her starched uniform is necessary to keep dust and lint from the room, since the instruments are of such a delicate nature that they could easily be damaged by tiny bits of lint or dust (Right) Motors, motors, motors—motors everywhere, as far as the eye can reach, but not a single one with a rotor in it. That's not so good, since a motor is not of much use without a rotor, but in this case this need not worry you since these motor frames are in production at the Westinghouse Electric & Mfg. Co. shops and all of them will be fitted with nice rotating rotors

Boilers for Turbine Tests

This is one of those articles difficult to classify as either fish or fowl. It tells in a direct way the care and attention given to testing turbines under operating conditions to insure that the turbine you buy performs exactly as expected. Yet the main interest in the article is in the boiler—a once through boiler of a type much in the public eye at present, especially in Europe, and which dates back to the early days in automotive history—to the days when the White, the Stanley and the Doble Steam cars were fighting with the Pope-Hartford, the Chalmers and the Buick gasoline cars for supremacy—to the days when these steam cars rushed up mountain grades showing a feathery plume of exhaust to the gasoline cars being nursed up in low with boiling radiators. The gasoline car finally emerged the victor, but a new field for this type of boiler has recently been opened up in railroad service. This article indicates that the boiler has possibilities in various specialized industrial applications.

BY C. F. JENSKY

Chief Engineer Murray Iron Works Co.
Burlington, Ia.

DEVELOPMENT of automatic steam generating units for motive power purposes was an important consideration in the early days of the automobile industry before the rapid development of the internal combustion engine pushed steam into the background. Automatic combustion and feedwater control systems are now widely used but the development of complete units that can be started, operated at widely varying loads and stopped about as easily as an internal combustion engine has been dormant.

In recent years great progress has been made in the use of high pressure high temperature steam in the power field. The resulting improvement in efficiency of steam plants, together with startling new developments in the transportation industry, has revived interest in automatic steam generating units. Recently an airplane powered with an automatic steam plant was successfully flown. A streamlined train on the New Haven Railroad is powered with a new type of steam power plant utilizing an automatic high pressure boiler. Compact, high pressure, automatic steam generating units, developed primarily for transportation service, will no doubt find many applications in stationary power plants. An interesting installation of this kind, which has been in successful operation for the past two years, is described below.

Many small steam turbines are now built for high pressure high temperature service. It is desirable to test these turbines under their actual designed operating steam conditions. The designed steam pressure and temperature are frequently higher than that available in the regular factory steam system. In this type of testing, involving not only steam consumption checks but routine inspection and adjustment runs, the operating conditions and steam flow requirements vary drastically. It is, therefore, desirable to provide a steam generating system that can be operated economically over a wide range of pressures and temperatures with sudden fluctuations of steam flow from zero to maximum capacity.

The Murray Iron Works Co. of Burlington, Iowa, solved this problem by installing a Besler automatic boiler for turbine testing service. The boiler with its related auxiliaries as shown in Fig. 1 is installed on the turbine test floor where it is under control of the regular turbine test crew. Figure 2 shows a water and steam flow diagram for the complete test hook-up.

Condensate must be collected and weighed as part of the turbine test procedure. This condensate is stored in a large steel tank below the test floor and is used for boiler feedwater as required. The boiler feed pump is a high speed, 2-cylinder, V type, electric motor driven, double acting, reciprocating pump. The pump is kept under a positive suction head by means of an elevated gravity tank which is kept filled with condensate by a motor-driven centrifugal pump. The feedwater is heated in a closed heater using steam at 150 lb. pressure, supplied by the regular low pressure steam system. By driving the boiler feed pump with an electric motor and using the regular factory steam supply for the feedwater heater, the entire steam output of the boiler is available for test purposes. This is a modification of the completely automatic, self-contained unit where heat and power for all auxiliary services is taken from the boiler itself.

Condensate from the feedwater heater is drained to the storage tank and normally supplies the make-up requirements. The low pressure steam line is connected to the surface condenser so that, if necessary, additional condensate can be provided between runs. This line

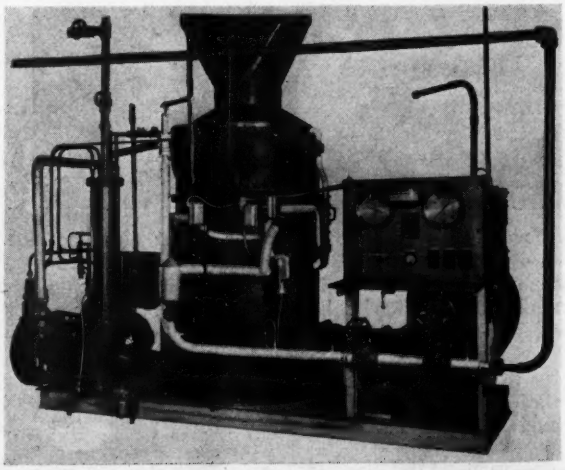


Fig. 1. From zero to maximum load in 4 sec.—heat releases of 500,000 B.t.u. per cu. ft.—complete automatic control by steam temperature and pressure—complete flexibility—8400 lb. per hr. of 1000 lb. steam from a unit 4 ft. in diameter and 6½ ft. high. That is hardly conventional practice but this once through boiler with no drums, headers or storage space is doing it consistently as part of a regular routine for testing turbines

is disconnected during tests to eliminate the possibility of test error through leakage. Other possible sources of leakage affecting steam flow measurements also receive consideration. The surface condenser tubes are lacing packed at one end and are thus subject to some leakage. Leakage tests are made at frequent intervals and the packing kept tight. The exhaust relief valve is so located within the test room that leakage from this valve would be readily detected. When operating under vacuum some vapor is lost through the air ejector. The condenser is properly baffled to cool the air and vapor before reaching the ejector and since the total capacity of the ejector is only about 25 lb. of dry air and vapor per hour, the vapor loss is a very small percentage of the total steam flow, corrections are easily made.

low pressure steam, it is possible to obtain moderately superheated steam for more reliable test results.

Description of Boiler

The Besler boiler is a vertical, continuous flow, water tube, force feed, non-water level, counterflow boiler having no drums, headers or storage tanks. There are no large volumes of stored water or steam. It has a rating of 7500 lb. of steam per hr. at a pressure of 1000 lb. per sq. in. and 750 deg. F. total temperature. Under test it has produced 8400 lb. of steam per hr. The boiler proper is approximately 4 ft. in diameter and 6½ ft. high. It has 385 sq. ft. of heating surface and a combustion chamber of 23½ cu. ft. In effect it is a long pipe in coil form, enclosed in a cylin-

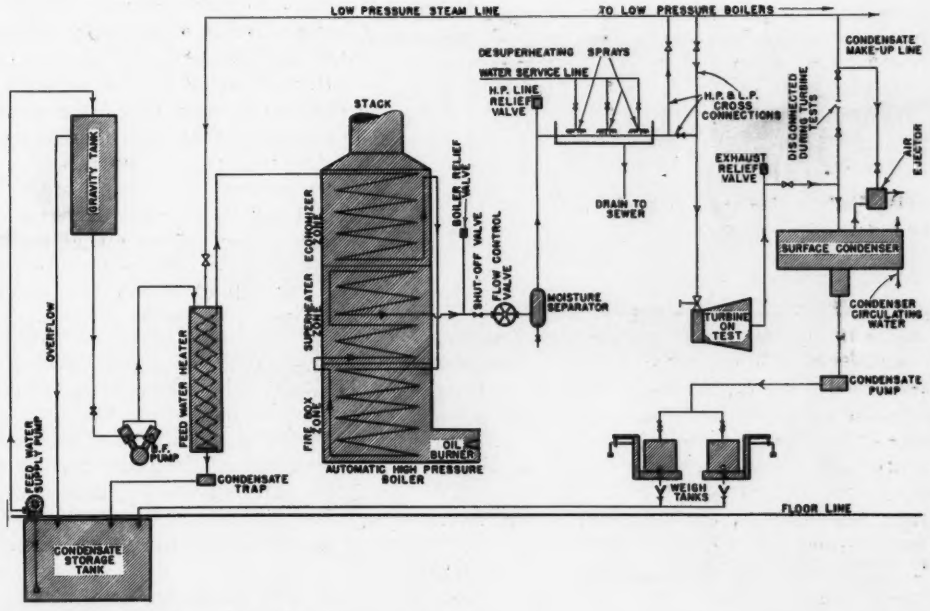


Fig. 2. Steam and water flow diagram for the automatic high pressure Besler boiler used on Murray's turbine test floor

The boiler is operated at a pressure of approximately 1000 lb. per sq. in. ga. The steam is throttled to any desired lower pressure through a non-automatic flow control valve. The steam temperature can be varied by means of a simple adjustment at the boiler but it has been found desirable to operate the boiler at a high temperature and then cool the steam to the required temperature at the turbine by means of water sprays on the steam line. This has been found to be an accurate and flexible method of controlling the steam temperature, especially when only a few degrees of superheat is desired. The steam line is protected by a relief valve which is set to suit the maximum pressure required for the particular turbine on test.

In addition to supplying steam for high pressure high temperature turbines, the high pressure boiler is sometimes used to supplement the low pressure steam supply. This is convenient when an unusually large quantity of low pressure steam is required. The low pressure steam normally contains about 3 per cent moisture. By mixing high temperature steam with this wet

drical casing and heated over its entire length. Water is pumped into one end of the tube and steam emerges from its other end. A portion of the circuit is divided into two parallel circuits.

The boiler can be conveniently described as having three parts or zones. The top being farthest from the fire is referred to as the economizer. The water enters this section and passes toward the fire through a series of 16 spaced "pancake" coils. The tubing in these coils grows gradually in diameter as the circuit approaches the fire. This allows for the increased volume as steam is generated in the tubing.

500,000 B.t.u. per Cu. Ft.

From this economizer zone the steam and water passes to the lower section of the boiler referred to as the fire box zone. In this section the tubing is tightly wound in the form of a helical coil which forms a complete saturated steam wall for the combustion space. The heat released within this space is about ½ million

B.t.u. per cu. ft. per hr., so this steam wall is an essential feature of the construction of the boiler.

The superheat zone is located between the combustion and economizer zones. The superheat section is cleanable throughout. The clean-out fittings are of the oval type with internal plugs and gaskets. Experience has shown that scale deposits, if any, occur only in this superheat zone and simple adequate cleaning plugs assure a quick and positive means of removing all types of boiler scale. At an operating pressure of 1500 lb. per sq. in. the tube stresses are held to approximately 5000 lb. per sq. in. throughout the economizer and fire box zones. The stresses are somewhat lower in the superheat zone.

The tube assembly is mounted on a welded steel frame work with cast steel rings. The boiler casing is built in three parts, which corresponds to the three zones mentioned above. This casing also forms an insu-

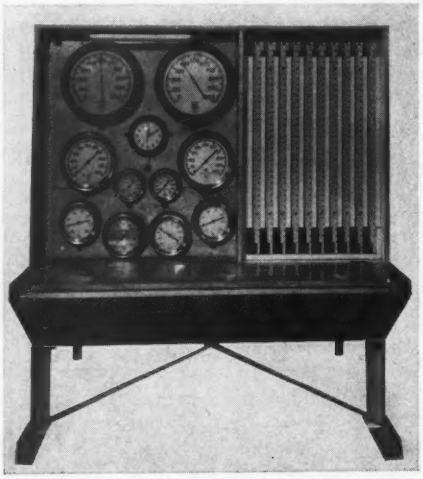


Fig. 3. This special panel was constructed to facilitate the turbine test procedure. The desk part with conversion tables steam charts, etc., permanently mounted, opens up and forms a cover for the panel when it is not in use

lating air-tight shell with inner and outer sheets separated by insulating material. The outer casing is formed of rolled steel. The inside casing adjacent to the economizer and fire box zones is formed of heat-resistant stainless steel. The inside of the casing adjacent to the superheater section is formed of nickel chrome alloy developed for corrosion and temperature resistance. Steel tubing is used for the coils. The outside of the casing is separated from the inner casing by 2½ in. of high temperature insulating blocks. One side of the superheater casing adjacent to the superheater clean-out plugs is formed as a door, which is made easily removable so that access can be had to this section for cleaning purposes.

Control

The boiler control is fully automatic, the operator only having to start and stop the unit, and make such pressure and temperature adjustments as are required to suit different turbines on test. Control is secured by pressure and temperature responsive elements which operate to bring on the fire when required and to introduce the correct amount of water by controlling the feedwater pump.

There are four thermostats, two of which are located in the water wall surrounding the combustion space. The third thermostat is attached to one of the superheater tubes and registers the temperature of the tubing in this zone. The remaining thermostat controls the oil burner and water pumps as a function of the steam temperature and pressure. If either the tube temperature or the steam temperature should rise to a dangerous point, these thermostats automatically break the electric circuit and cut off the fire. These four thermostats are all connected in series and all of their electric contacts must be closed in order to allow operation of the burner.

Control of the temperature is obtained by introducing a deficiency of water into the economizer section whenever the fire is burning. This results in a rise of steam temperature which actuates the control thermostat to increase the supply of water which is introduced at the inlet of the boiler and in addition a small quantity of water is also injected into the superheater section in advance of the superheater thermostat to directly actuate this thermostat and more quickly restore the desired temperature at the boiler outlet. This temperature control operates so effectively, accurately and rapidly that the issuing steam temperature varies only a few degrees regardless of the boiler output.

0 to Maximum Capacity in 4 Sec.

This temperature control is effective for a minimum of about 50 deg. F. of superheat. The de-superheating sprays noted above have, therefore, been found desirable for some operating conditions. The boiler is designed to go from zero output to maximum output in four seconds and the turbine throttle can be closed instantly without detrimental effects on the boiler. The flow of boiler feedwater into the boiler is controlled for this wide range of output by electric solenoid valves.

The oil burner is of the pressure atomizing type, utilizing forced draft. The mixture control is maintained by a control mechanism actuated automatically by air flow to the burner to meter the quantity of fuel in proportion to the amount of air. The forced draft blower is of the multivane type, driven by an electric motor. Ignition is secured by dual, high tension, electric sparks, operating two separate sets of electrodes supplied by independent high tension transformers. Electric current for the automatic controls is supplied by an ordinary storage battery. Fuel pumps are of the gear type. Positive return of excess fuel to the fuel tank is provided by a separate pump.

In addition to the over-pressure and over-temperature safety devices noted above, the boiler is equipped with the usual safety valve for protection against excessive pressure.

To put the boiler in operation, it is merely necessary to close electric switches controlling the water pumps, fuel pumps, blower and the ignition system. The boiler can be steamed up from cold to full capacity in approximately five minutes. This feature, together with great operating flexibility, has made this a successful installation for turbine testing service.

Deterioration of Boiler Sheets

During the life of a boiler, normal temperature strains and working conditions have their deteriorating effects the extent of which the engineer in charge should know. Some vulnerable points which need careful watching are cited.

By C. C. CUSTER

WHEN a hot steel ingot is rolled, pressed and stretched out into a sheet for boiler purposes, it acquires an improved tenacity of fiber and tensile strength which especially fit it for the purpose for which it is intended. On the other hand, this same sheet of steel, after it is fabricated into a boiler, may go through various changes or be subject to sundry unfavorable influences that have a tendency to deteriorate its physical condition from fibrous to crystalline or granular structure and to decrease its tensile strength and increase its brittleness. Even ordinary wear and tear takes something out of a boiler. The mere fact that a boiler has been in use for 30 yr. or more is sufficient basis for the conclusion that its tensile strength is impaired and therefore it will be advisable to reduce its working pressure.

Boiler inspectors are alert to detect bags or distortion, laminations, pitting or corrosion, grooving, mud-burns, fire-cracks, typical lap seam cracks, flange cracks, sprung calking, stretched rivets,—all of which are to be interpreted as "symptoms of distress," showing that the metal has suffered some sort of deterioration in use. The boiler inspector learns by experience and observation just what parts of boilers are most vulnerable and where these defects are most likely to be found.

The operating engineer may be interested in how to locate these points of danger. There is no use to look for trouble where it is not found.

As an example of crystallization one can examine tube ends that have been removed for safe-ending. When the bead is bent back it generally breaks off and the crystalline character of the fracture can be noted. The burned ends are cut back and a new piece is welded onto one end and after the ends are annealed the tube is put back in.

A lamination is a defect in a sheet where it has a tendency to separate into layers or slivers. It generally is supposed to have originated in process of manufacture,—when the top of the ingot was discarded they did not get low enough and there was a "pipe" in the ingot that developed into a lamination. Laminations were also sometimes found in the old-time wrought iron sheet caused by impurities in the iron. Nowadays laminations are not often found in steel boiler sheets on account of improvements in manufacture and rigid inspection.

Not long ago the writer found a lamination in the bottom of the internal furnace of a Scotch marine boiler about the diameter of a silver dollar. We dug little slivers out of this hole till we got down to the solid metal about half way through the sheet,—then filled up the hole flush by autogeneous welding,—this being a sheet that was convex to pressure. When the outer layer of a lamination bulges out from the inner it is called a "blister." Such a defect is not often found. It generally calls for a patch.

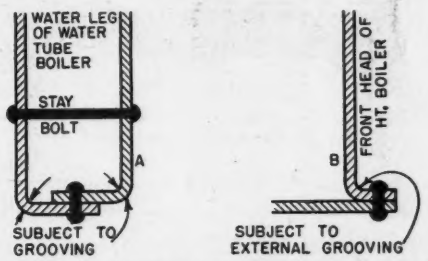


Fig. 3. Details of boiler construction subject to grooving

FIG. 1

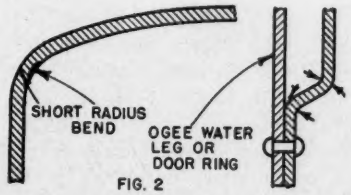


FIG. 2

Fig. 1. Dished head with plain manhole flanged in
Fig. 2. Construction employing short radius bend

Where Grooving May Occur

Grooving of a boiler sheet generally is located on one side or the other where a boiler sheet is bent to a short radius,—see Figs. 1, 2 and 3. Slightly exaggerating the condition at the short radius bend in Fig. 2, it will be noted that the outside fiber of the sheet may be stretched and the inside fiber be wrinkled and if there is any tendency to corrosion in the water, or at the fire side, grooving will start there.

Formerly when it was the practice to maul out bumped heads over a form, a flange crack would occasionally be found as at B, Fig. 1. Mauling out is no longer considered a satisfactory way to form and flange

a flanged head. In the shops of the larger steel companies, now bumped heads with flanges are "hot spun" on a special machine which does not injure the metal in turning the flange and flange cracks and grooves are now rarely found.

Mud-burns are often found at the mud-ring of vertical tubular boilers. The first sympton of mud-burn is usually that the stay-bolts at the lower part of the stayed portion of the fire-box begin to leak at the thread at the outside sheet. When the boiler is opened there will be found a considerable deposit of mud or scale

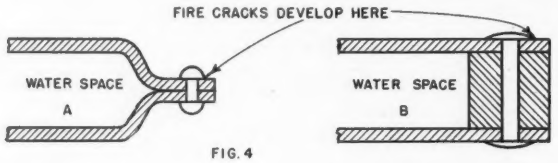


FIG. 4

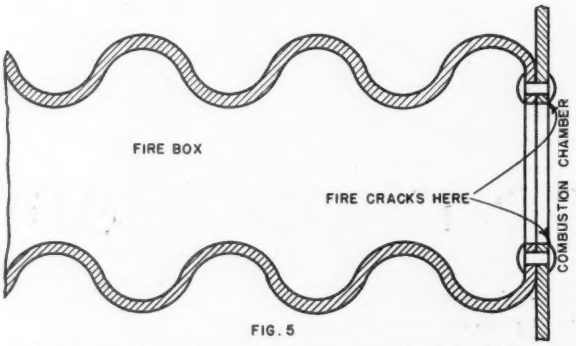


FIG. 5

Fig. 4. Fire door ring construction for vertical tubular boilers
Fig. 5. Corrugated furnace joint

inside. Of course if allowed to accumulate it will finally lead to a bag on the inner furnace lining just above the level of the grates.

Probably the commonest symptoms of deterioration is the fire crack. Fire cracks are generally caused by (a) exposure of the sheet to excessive temperatures, (b) continual and alternate heating and cooling of the part, or (c) strains set up by unequal expansion and contraction.

Poor quality of sheet may be a contributory cause also if the sheet contains more than the allowed percentage of carbon, manganese, sulphur, or phosphorus. Also if the sheet has been rolled too cold it may be unusually subject to crackage.

Generally the appearance of a typical series of fire-cracks on the girth seam of a horizontal return tubular boiler indicates that undue heating has occurred at this point, having been caused by the collection of excessive scale or sediment on the water side. Also in a horizontal return tube boiler fire cracks are sometimes found at the joint where the rear flue sheet is riveted into the shell. This is generally the result of allowing excessive deposits of scale to accumulate in the vicinity of the rear head.

Tubes Subject to Fire Cracks

Fire cracks caused by continual and alternate applications of high and low temperatures are frequently found in that part of the rear-pass tubes projecting upward into the rear upper drum of a three-drum bent tube boiler. The feedwater enters here and impinges on these tube ends so that they are alternately heated and cooled by the varying feedwater temperature; thereby in the course of time these tube ends become quite crystalline and brittle and cracks appear. These cracks are not considered dangerous unless they extend down into the tube too far or into and beyond the place where the tube is expanded into the drum, in which case it becomes necessary to change a tube. Another case where I have found a fire crack inside a boiler was a case where an engineer had put in a boiler feed pipe in a horizontal tube boiler where it discharged the feedwater directly onto a longitudinal seam and started fire cracks at the seam. It is very bad practice to have feedwater discharge onto a seam.

How expansion and contraction cause fire cracks is witnessed by the abnormal tendency of patches on the fire sheet of a horizontal tube boiler to take on fire cracks. The double thickness of metal at the edges of the patch causes the layer next to the fire to get extremely hot with the result that probably all three causes (a), (b), and (c) mentioned above, give rise to leaks at the rivets, or at the calked edge of the patch and to fire cracks from the calked edge to the rivets or between the rivets. Whenever a boiler with a patch on the fire sheet is heavily fired in hard service, the patch will generally not stand up long. Nor does it do any good to double rivet such a patch, as this only increases the area where there is a double thickness of plate between the water side and the fire side and the joint rapidly deteriorates. Electric seal welding does little good in this case as expansion and contraction strains will get in their deadly work.

Then again it is found that fire cracks are the natural result of certain types of design. For instance, fire cracks are often found around the fire door rings of vertical tubular boilers, whether these be built of the ogee form shown in Fig. 4-A, or they be of the wrought iron type shown in Fig. 4-B. The inference to be drawn is that the construction does not permit the water inside the shell to carry away the heat from these parts and maintain equable temperatures.

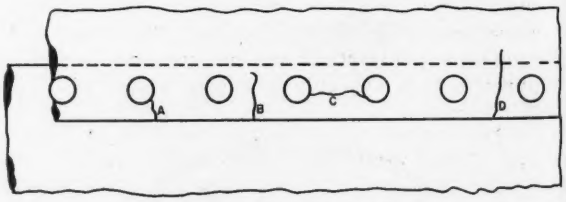


Fig. 6. Kinds of fire cracks on girth seams

Another typical and similar example is that frequently found in the Scotch marine boiler. In order that the corrugated furnace used with this type of boiler may be easily removed for repairs, the joint where the furnace is attached to the combustion chamber is often flanged inwardly, or away from the cooling action of the water space as shown in Fig. 5. Fire cracks are prone to develop at or near the edge of this joint unless the joint be protected by what is called a

furnace-mouth protector, which consists of a row of special fire-brick supported on a metal ring.

Fire Cracks on Girth Seams

Figure 6 shows several different kinds of fire cracks on the girth seam of a boiler for which different methods of repair are applicable. At A is shown a fire crack extending from the edge of the plate into a rivet hole. This may be repaired by first removing the rivet, then preparing the crack for welding by cutting out the metal at the crack so the result is a V-shaped groove, and then filling the groove with metal by autogenous welding, following which the rivet hole is reamed out and the rivet redriven. The crack at C between rivets is similarly repaired. Also the crack at B, but here a small hole should first be drilled at the end of the crack, to be sure we have got to the end of the crack, then Veed out and welded. If a crack as at D gets out too far beyond the edge of the sheet overlap, most inspectors will require the sheet to be patched. Therefore it is important that fire cracks be promptly discovered and repaired before they work too far into the sheet and are as yet susceptible of a welding repair.

Often when a bad girth joint is allowed to go too long it will begin to leak at the calked edge. In this case it is proper to conclude that the calking has been sprung by overheating and the rivets stretched so that it will be desirable to renew all the rivets along the affected area, then calk the joint and Vee out and weld all the fire cracks, in which case a permanent repair may be effected.

Another case where fire cracks are sure to be found is where some one puts a new set of flues into a vertical tube boiler and forgets to bead them at fire-box end; or when some one retubes a horizontal return tube boiler and neglects to bead them at the back head. These projecting tube ends are sure sooner or later to show fire cracks.

Cost of Ice In An Absorption Plant

Old Absorption System Plant was Rehabilitated and Operating Methods Improved with Resultant Saving in Fuel.

By H. A. CRANFORD

ALTHOUGH there are few absorption system refrigeration plants being built nowadays because of the high initial cost of installation, there are still in operation a large number of this type. But recently, I have heard of several owners of this type of plant who were thinking of abandoning them because they could not compete with more modern plants. One plant owner expressed himself as being unable to secure a competent engineer because of the system being complicated, and fuel cost made production cost soar out of reason.

The writer contends, and has always contended, that the engineers themselves are in a great measure to blame for the hard things that have been said about the absorption system, and believes that refrigeration can be produced as cheaply with this system as any other ammonia system built today. Of course where a new plant is to be built, where there isn't a sufficient supply of wasted exhaust steam, or where a copious supply of cold water is not available, it would be foolish to recommend an absorption system. But where these things prevail, or where such a plant already exists, the following facts and figures together with sketches, offer convincing proof that ice can be produced at a very low cost per ton.

As stated, the engineers are more or less to blame. They are unwilling to give the system the common sense study that they should, and as a result, are finding themselves up against it as the plant owner turns to the so-called automatic one-man plants, with the resultant lower wage. To the live engineer who really gives the principle of absorption the necessary study it offers the most interesting work. I make this statement after having erected, reconditioned, and operated practically every kind of refrigeration, ice and cold storage plant in a large part of this country of ours.

Test Results Cited

To back up this opinion, I offer the facts and figures taken from a log sheet in a plant that was built in 1919. And the tests and figures and other data were made by an outside, disinterested engineer, who used his own instruments, and was given a free hand and all the help he asked for. The test was over a longer period of time than the 24 hr. referred to here, but space would not permit the inclusion of more than one day's log. But even at that, after the test was finished, we improved on these figures somewhat.

The owner of the plant is an unusual man. Forty-five years in the business has made him an easy man

Table I. Data from Log Sheet

Grade of coal	"Moss" Nut 14000 B. t. u.	
Duration of test	24 hr.	
Water metered at 222 deg. F.	2,133 cu. ft.	
Weight of 1 cu. ft. of water at 222 deg.	59.58 lb.	
Total water metered to boiler and evaporator,	127,084 lb.	
Total coal burned,	9,000 lb.	
Total ash and clinkers removed,	430 lb.	
Average temperature of feedwater,	222 deg. F.	
Average steam pressure in boiler (From chart)	131 lb.	
Average steam pressure in evaporator, (From chart)	81 lb.	
Average temperature of escaping flue gas	454 deg. F.	
Average CO_2 (Carbon Dioxide)	11.6 per cent	
	Over Fire	Wind Box Pressure
Average draft in inches H_2O	0.16 in.	1.19 in.
Actual water evaporated per hour	5,295 lb.	
Coal burned per hour	375 lb.	
Actual evaporation per lb. of coal	14.12 lb.	
	Coal at mine	$2.00
Cost of coal delivered, per ton	Freight	2.92
	Total cost	$4.92
Cost of coal to evaporate 1000 lb. water	$0.1742	
Credited tons of ice produced during test period (Credited at 300 lb. per cake)	50.4	
Actual tons ice produced, cans filled with 320 lb. (20 lb. allowed for shrinkage and scoring)	53.76	
Credited tons of ice per ton of coal	11.2	
Fuel cost per ton of ice credited	$0.4393	
Engine room or production cost per ton other than chief engineers salary	$0.292	

to talk to and he understands what you are driving at. He will allow any reasonable experimental change that offers a promise of increased efficiency. The engineer that erected the plant, operated it for years with satisfactory results. At the beginning of the depression he died and several engineers were employed from time to time but the production cost gradually creeped higher. This, coupled with the falling demand for ice became more than noticeable. The plant still paid dividends but the owner realized that he was burning around 7 t. of coal a day, yet he wasn't getting capacity.

Another engineer was called in, one who had a reputation as a real refrigerationist. He saw in a few hours that experimental changes had been made. Changes that any man with a full knowledge of the principles of refrigeration, especially as applied to the ammonia absorption system, would never have made. Figures 1 and 2 show how the plant was rearranged. All valves, especially by-pass valves were reconditioned where possible, and new ones installed where needed.

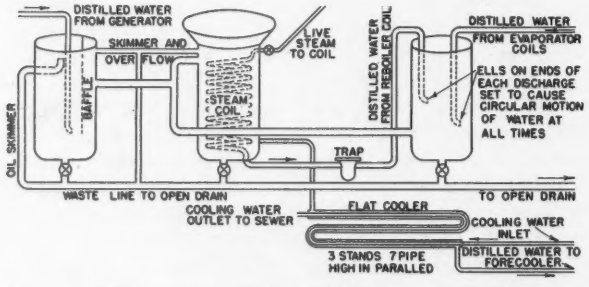

DISTILLED WATER FROM GENERATOR
SKIMMER AND OVER FLOW
BAFFLE
OIL SKIMMER
LIVE STEAM TO COIL
STEAM COIL
DISTILLED WATER FROM REBOILER COIL
DISTILLED WATER FROM EVAPORATOR COILS
ELLS ON ENDS OF EACH DISCHARGE SET TO CAUSE CIRCULAR MOTION OF WATER AT ALL TIMES
TRAP
WASTE LINE TO OPEN DRAIN
TO OPEN DRAIN
COOLING WATER OUTLET TO SEWER
FLAT COOLER
COOLING WATER INLET
3 STANDS 7 PIPE HIGH IN PARALLED
DISTILLED WATER TO FORECOOLER

Fig. 1. Distilled water system showing skimmer tank, surge tank, reboiler and flat cooler

The present operator, taking charge in the late spring, used every moment of shut down periods to give the system a thorough cleaning, and make as many repairs and changes as was possible. The result was that the fuel consumption was lowered to 4.6 t. per 24 hr. Perfect coöperation on the owner's part made this possible.

The boilers in the plant are water tube, cross drum type with 63, 4-in. tubes 18 ft. long, 7 tubes wide, 9 tubes high, 42-in. drum 6 ft. 7 in. long. They are fired with a popular make of underfeed stoker using stoker nut coal. The feedwater is taken from the city mains or private wells as desired. There is a cold water meter on the suction side of the pump, and a hot water meter on the feed line where it leaves the exchangers.

Course of Water Through Plant

The boiler feed pump forces the water through the inside pipe of double pipe exchangers made up of three stands, seven pipes high, 20 ft. long connected in parallel. From there it passes through another exchanger of three stands in parallel, four pipes high, 20 ft. long.

Through the outer pipe of the first exchanger passes the distillate, or condensate, from the steam coils of the ammonia generator, on up to the skimming tank on the roof. Through the outer pipe of the second exchanger passes the condensate from the steam evaporator coils. This is discharged through a trap into the surge tank on the roof. The skimmer and surge tank empty into the reboiler. Condensate from the coil in the reboiler is also trapped to the surge tank. The only condensate that is discharged into the skimmer is that from the generator. This condensate carries some oil from the exhaust steam, although most of it is separated and trapped off before the exhaust passes into the generator steam coils. The oil is skimmed off

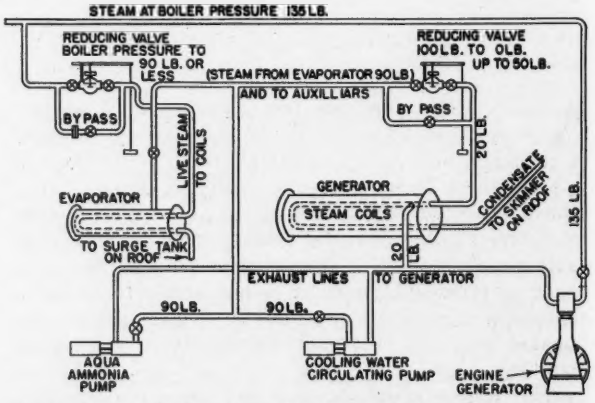


Fig. 2. Steam and exhaust connections to evaporator, generator, pumps and engine

regularly and there is seldom the least trace of any on the top of the ice cakes. After the boiler feedwater passes through the exchangers it is very seldom under 200 deg. and in hot weather, with the plant going full capacity it often reaches 230 deg. F.

Of course all the exposed lines are well insulated. The boiler feed pumps are regulated to keep an even water level in the boilers and since there is very little fluctuation in the steam load of an absorption system, this is very easily done.

In the use of double pipe exchangers for feedwater

Table II. Operating Conditions in Plant During Test Run

Number of gals. water circulated through refrigeration system for cooling purposes	200 g. p. m.
Temperature of water to ammonia condenser	66 deg. F.
The water passes through the double pipe condenser to the double pipe absorber	
Temperature of the water leaving the absorber	98 deg. F.
From the absorber to D. P. rectifier, Temperature	98 deg. F.
From D. P. rectifier to waste. Temperature	140 deg. F.
Part of water from the absorber goes to weak liquor cooler at a temperature of	98 deg. F.
Temperature of water leaving W. L. cooler	110 deg. F.
Temperature of gas from rectifier to condenser	140 deg. F.
Temperature of weak liquor leaving generator	245 deg. F.
Temperature of weak liquor from cooler to absorber	108 deg. F.
Temperature of rich liquor from absorber to pump	112 deg. F.
Temperature of anhydrous ammonia from condenser	88 deg. F.
Generator steam pressure	20 lb.
Generator ammonia pressure (high side)	170 lb.
Absorber pressure (low side)	20 lb.
Brine temperature average for 24 hr. period (15 min. period readings)	14 deg. F.

heaters. The plant is assured of hot feedwater because of the rapid transfer of heat in this type of exchanger. By using two exchangers, the benefit of the heat from the condensate from both the coils of the generator and steam evaporator is secured. Also lowering the temperature of the condensate from the generator coils gives better separation of the oil in the skimmer.

After the condensate is reboiled it passes down through another double pipe flat cooler consisting of three stands seven pipes high and 20 ft. long. Water at 66 deg. F. temperature flows through the outer pipe and discharges to waste. The distilled water, after passing through this flat cooler, passes to the fore cooler tank. The gas returning from the evaporator passes through coils in this tank and cools the water with which cans are filled to a temperature of 46 deg. F.

The steam evaporator, upon which depends the greater part of the supply of distilled water is the shell and coil type, the coils having approximately 256 lineal ft. of 1½-in. pipe in them. Live steam from the boilers is fed into the coils of the evaporator through a pressure reducing valve. The valve is adjusted to generate steam in the shell at 80 to 85 lb. pressure. This steam is used to drive all auxiliaries and to supply live steam make up to the ammonia generator, the exhaust steam not being sufficient. Between the evaporator and the generator another pressure regulating valve is used. This valve assures an exact pressure on the generator at all times. The regulator valves are of the plunger type with oil dash pots to prevent slamming and chattering. Extensions have been placed on the weight levers that extend to within easy floor reach and weights provided with which the steam pressures can be limited to 1 lb. variation in pressure.

In my experience with absorption plants, in nearly every one there has always been a shortage of distilled water. And where the evaporators were in use nearly every operator would always increase his steam pressure on the evaporator with the idea that he would increase the amount of distillate. The fact is when the steam pressure is increased, distillate will decrease. The function of the evaporator is two fold. First: To condense steam from the boiler through the evaporator coils, to make distilled water. Second: To furnish steam at low pressure, which also means, at a lower temperature, to run the auxiliaries. This means lower temperature steam from auxiliaries exhaust to the generator and lower live steam makeup for the generator. The lower the pressure can be carried, and still be sufficient for the auxiliaries, the faster it will condense in the generator coils. Also the more water fed into the shell of the evaporator, the more distillate will be produced in the evaporator coils, and the lower the pressure to the auxiliaries, the more steam will be needed from the evaporator.

It stands to reason, then, if there is a shortage of distilled water, the logical thing to do is not to *increase* the evaporator pressures but to *lower* them, as low as it is possible to lower them, and still have sufficient pressure to operate the auxiliaries.

As stated before, the boiler feedwater to the pump is metered while it is cold and to the boiler after it is heated. Ice is harvested on exact schedule, 14 cans an hour, three hundred and thirty-six 300-lb. cakes each 24-hr. period. During a test run for a seven day period, an average of 16,000 gal. or 133,333 lb. of water went to boiler and was evaporated each 24 hr.; 336 cans were filled with distilled water averaging 320 lb. to the can, which amounted to a total of 107,520 lb. This shows a loss of 25,813 lb. of water, which at first seems large, but when the nature of the water is considered, is very small.

Water Filtered to Remove Iron

The filters are back washed to sewer twice daily to get rid of fine particles of iron that is in the raw water that nothing seems to overcome. Then there is a vent from the condensate receiver, one from the receiver from the evaporator coils, one on each of the regulator valves, and all four blow continuously through a ⅛-in. opening. There is also a trap and separator in the exhaust lines to generator to separate oil from the exhaust steam. There is also a considerable amount of water carried over with the oil skimmer. This loss could be reduced some but this way, absolutely oil free clear ice is secured at all times. An 8 by 9 in. high speed piston valve engine drives a 200 ampere direct current generator to supply current for agitators, hoist and ice storage compressor. Two motors drive this compressor, and when not running the plant, city power takes care of the ice and meat storage room.

On the test run the reader will notice that 11.2 t. of ice were produced per ton of coal. Of course this was when the plant was running at capacity, but the average for the year will easily run 10 t. per ton of $4.92 coal. This average is secured by letting the ice storage of 300 t. become almost exhausted and then starting up, running full capacity until the storage is full again, then freezing down to very low temperature.

The production cost in this plant compares very favorably with the cost of production in more modern systems. With a fuel or power cost of $0.4393 per ton of ice and lubrication, maintenance, etc., about the same as other systems, we can see no reason why those owners who have their money invested in absorption systems, should think of dismantling them.

Readers' Conference

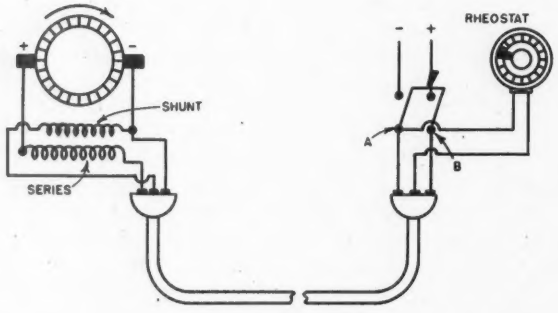
Motor Fails to Build up Voltage as Generator

A CERTAIN factory was in need of a direct current generator for electric lighting and to drive small motors around the plant. There was a 75 kw. compound wound, direct current motor at one of the other plants which was not in use, and it was decided to ship it to the plant in question, and utilize it as a generator.

This was done and the machine arranged to run by a belt from the flywheel of an existing engine. A second hand switch board had also been procured and set up in the engine room.

The plant electrician had made the necessary connections between the machine and the switch board, the machine was belted and brought to speed, but failed to build up the voltage.

All the resistance was cut out at the rheostat, and while it was possible to see a small fluctuation of the volt meter point, the voltage would not come up. At first it was thought that the speed of the machine was too slow, but this was checked and found to be in accordance with the rated speed on the name plate.



The writer, who was operating engineer of the plant at the time, reasoned since there was enough voltage to move the voltmeter pointer slightly, that what excitation there was came from the series field winding and that the shunt field was open or opposing the series field.

The connections are shown in the accompanying sketch.

Knowing that the change could do no damage, the engineer suggested that the lead from the rheostat to the bottom terminal of the main switch at A be shifted to the other terminal of the switch, indicated at B. This was tried, and sure enough, the voltage built up at once.

The wiring between the generator and the switchboard was in conduit and the electrician had evidently lost identity of the leads in pulling them through the conduits and had both ends of the shunt field hooked to the negative side of the machine.

Instead of being a "lemon," as it was feared for a time, this proved to be a "sweet running" machine, and with the connections corrected, it gave, and to the best of our knowledge, is still giving good service.

Coffeyville, Kans. EARL PAGETT.

Explosions in Flues of Oil Fired Boilers

A SERIOUS explosion occurred in one of the flues of an oil fired boiler. The boiler had two furnaces and when starting up, the oil burners in one furnace lighted correctly, but in the other the burners failed to light after three attempts and the combustible gases from these on entering the flue were ignited by the gases from the first furnace, which resulted in a serious explosion.

To prevent accidents of this sort the flues from different furnaces should be entirely separate and the chimney should also be subdivided. In the case of burners failing to light, the oil supply should be shut off and the air inlet to the boiler front and the damper opened, so that any oil vapor may escape. A second attempt to light the burners should be postponed until all the oil vapor has escaped from the chimney.

It is also advisable to preheat the fuel and the injecting medium and to pay attention to the condition of the burners, so that uncertainty of ignition is reduced to a minimum, as, in the event of burners failing to light, it takes some time to remove the oil vapor from the flues and chimney.

London, England. W. E. WARNER.

Engine-Room Records

MUCH has been written and much more will probably be written about the value of keeping a plant log in a refrigeration plant engine room. Some operators claim that it is a waste of time to keep daily records; others that it is too much bother. Actually it is neither.

Very recently this was borne out in our plant when a checkup of the past season's operating records revealed that a change in ice pulling and storing procedure would have saved $200. Without daily records of ice pulling, compressor operation data, and electrical meter readings this calculation would have been impossible.

Another case was that of a change in prime mover. On the face of the matter a change from steam to Diesel drive appeared proper and economical. A study of operating records proved that reducing use

of steam by half (used for peak load only) and a change to electricity for the balance would be a better all round proposition.

In drawing up a plant log, each individual installation is different and the daily report sheet should be adapted to the plant. In our plant we use a daily report sheet made out in duplicate, one copy being removed and sent to the office, the other remaining in a book in the engine room. From this daily record the chief engineer fills in a monthly sheet. The exact form of these reports has been changed several times, and other changes may be made in the future to secure the necessary data in the best possible form.

In some cases the none-existence of an engine room log is not entirely the fault of the engineer. Often in small plants the management does not realize the need and hence does not require one. Often too, the engineer is kept in ignorance of the cost of electrical power, coal, water, etc. He is not encouraged to know any more about the plant than enough to keep it operating. That is wrong, for it is only by complete cooperation between management and engineering, together with complete records, that a refrigeration plant can be operated to the most efficient and economical advantage of all concerned.

Williamson, New York — HARVEY A. PRATT

Boiler Patches

EFFICIENCIES of single riveted seams for various plate thicknesses and rivet pitches are given in Table I of the article Boiler Patches which starts on page 131 of the February 1938 issue of POWER PLANT ENGINEERING. It has been drawn to our attention by J. P. Morrison, assistant chief engineer, The Hartford Steam Boiler Inspection & Insurance Co., that the table as printed has three errors which should be corrected. The efficiency for ½ in. plate should be 55.5 instead of 52.5 per cent; for 21/32 in. it should be 46.7 instead of 51.4, and for 11/16 in. it should be 50 instead of 51.4.

Effect of Preheated Air on Flue Gas Temperature

IN THE FEBRUARY issue Mr. J. R. Darnell raised the question of whether preheated air decreases flue gas temperatures. I believe the question to be academic. Preheated air would most generally come from an air heater, and when an air heater is used the temperature of the flue gas leaving the boiler makes little, if any, difference from an operating point of view. The important factor is the temperature of the gases leaving the air heater. The boiler end temperature is important to the designer in proportioning the relative amounts of boiler and air heater heating surface, but once the unit is set there is very little that the operating engineer can do about it.

The only way that a satisfactory answer to the question can be obtained is to run a series of comparative tests on the same boiler, both with and without an air heater. This would not be as easy as it sounds. Very few commercial organizations would be sufficiently altruistic to sacrifice from five to seven per cent efficiency for a considerable period of time just to settle a purely theoretical argument. For this reason I am inclined to discount to some extent the quotation of D. J. Mosshart: "inspection of the data from a number of tests with both cold air and preheated air shows very little justification for the statement that preheated air reduces the temperature of the gases leaving the boiler." Were these tests with and without preheated air all conducted on the same boiler? If so, were the runs with cold air made under conditions comparable to the runs with preheated air?

Attempts to answer the question from a theoretical standpoint must also be unsatisfactory because of the great number of imperfectly understood variables involved. No one has yet devised a method of calculating furnace temperatures that is absolutely rigorous for any furnace under any conditions. Many methods are in vogue today which yield very close approximations, but all too often these methods fail to check pyrometer readings by surprisingly wide margins. Of course pyrometers are not infallible, but their readings are sufficiently acceptable to cast some doubt upon the accuracy of the computation. Similar statements may be made with respect to convection and radiant heat transfer between flue gas and metal.

The question of the proper amount of excess air to be used is also a question that can be best answered by trial and error. I heartily agree with Mr. Darnell's statement that the use of preheated air does not vaccinate the operator against careless firing. But even if the same excess air is used in both cases, a boiler operating with cold air will require more air than a boiler operating with preheated air. Assume that an air preheater will increase the boiler efficiency five per cent, say from 80 per cent to 85 per cent. Then for every million B.t.u. absorbed by the steam the boiler will have to supply $1{,}000{,}000 \div .85 = 1{,}176{,}000$ B.t.u. in the case of the air heater as against 1,250,000 B.t.u. without the air heater. This is a difference of 74,000 B.t.u. of fuel, and figuring roughly one pound of air for 1200 B.t.u. of fuel it means that for each million B.t.u. absorbed, a boiler operating with cold air will require 60 pounds of air more than a boiler operating with preheated air. The rate of heat transfer between the flue gas and the tube metal increases with the temperature, so that while there is a higher transfer rate with preheated air, there is a greater weight of gas available with cold air. Thus it may be seen that the temperature leaving the boiler is not very easy to predict.

In the original article there appeared a chart which showed the drop in gas temperature against the per cent of tube surface passed over. This chart is probably correct qualitatively, but not quantitatively. It would require terrifically high temperatures of preheat to raise the furnace temperature 250 deg., and while I do believe that the curves cross, the common point would probably be nearer 90 per cent of the surface than 40 per cent.

Recently I was looking over the design figures of a 350 h.p. boiler, which was to operate at something over 300 per cent of rating. The prospective purchaser wanted figures for both cold air and preheated air. The predicted efficiencies were 85 per cent with a preheater,

and 79 per cent without. The expected furnace temperature was 2175 with preheated air, and 2140 without. The air was to be preheated to about 425 deg. with a gas temperature drop through the preheater of about 275 deg. The temperature of the gas leaving the boiler was practically the same in both cases.

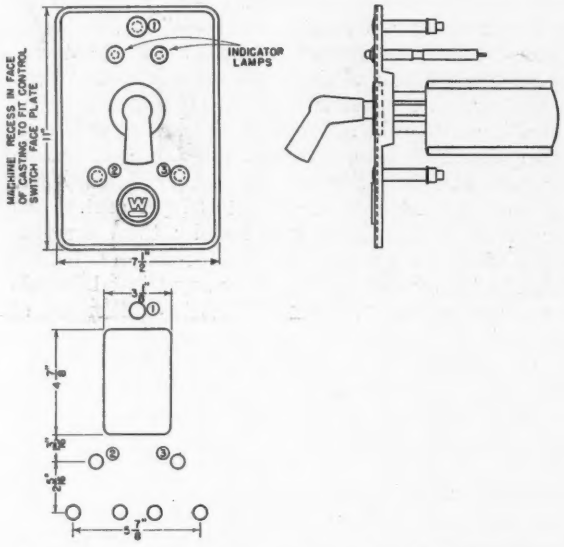
I realize, of course, that one isolated case does not prove anything, especially in the light of what has been said previously about the reliability of computation methods; but I do believe that it provides some indication of what might be expected.

Long Island City, N. Y. G. CAMPBELL KOHLAR.

Switchboard Cover Plate

THE ACCOMPANYING SKETCH shows a switchboard cover plate that was devised when a central station increased the size of its oil circuit breakers and changed the control from manual with rods and bell cranks to electric solenoids operated from a storage battery.

As will be seen from the sketch no new openings in the slate panel are necessary and old openings not used are covered by the plate. In addition, the new plate is neat in appearance and inexpensive to fabricate. Old manually operated breakers were Westinghouse F-11s and F-22s; new breakers are Westinghouse F-100s.



It is of interest to me that when the drawings were submitted to the manufacturer they were noted by auother customer doing similar remodeling work and the second customer actually used the new plates before the original sponsor received his shipment.

Hibbing, Minn. ARTHUR L. BENNETT.

Rubber Mountings Step Into Industry —Correction

WALTER C. KEYS, author of the article under the above title appearing in the March issue, has called attention to an error of omission from his submitted manuscript which was not detected until after publication. He writes: "On page 198 appears in parenthesis (number of vibrations per minute equals 188 ÷ static deflection in inches). This is absolutely incorrect and should be: (number of vibrations per minute equals 188 ÷ square root of static deflection in inches)." Mr. Keys also deprecates the use of the word "silent" which introduces the subtitle of the article and was written by an enthusiastic editor. His comment is: "I endeavor always to be reasonably conservative and I never lead anyone to think that we can obtain silent operation. The proper word is "quiet" operation.

Hot Bearings on Fans

THERE are a number of reasons for bearings running hot on large fans of blast wheel type, though in nearly every case the trouble is with the lubrication in one way or another. Cases have been encountered where fans drawing the air into a housing from the side were creating sufficient suction to draw oil from the bearing on that side leading it along the shaft. Such a condition can be detected by examining the shaft for traces of oil, and it can usually be cured by fitting a tight leather washer or metal baffle on the shaft in such position as to mask the end of the bearing from exposure to fan suction.

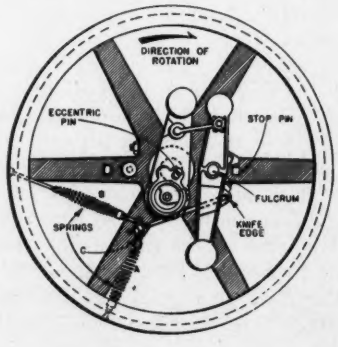
Admittedly, in more modern types of fans and bearings, conditions like the above are not so often found. Another thing that is capable of causing a heated bearing is lubrication of both bearings with a common grease line leading from a single cup or fitting, as the case may be. This is not good practice, and yet it is a thing that is often done. The trouble with such an arrangement lies in the fact that if one bearing has a little more looseness in it than the other, it will offer less resistance to the inflow of grease. Thus, lubricant flows freely into the looser bearing, while the other one is largely starved. The bearing that does not get its grease will then of course run hot and cause trouble. A grease cup or a grease line for each bearing should be the practice if one would insure the proper amount of grease reaching the bearing.

Peoria, Ill. JOHN E. HYLER

Steam Engine Governors

IN A MASSACHUSETTS license examination, the following question was asked, and I would appreciate the answer:

"You have two American-Ball angle compound engines, driving direct current generating units. When



Arrangement of the governor as used on the American-Ball engine. Two springs are used to counteract the effect of centrifugal force. Tightening spring B and slacking spring A makes the governor more sensitive. Tightening both at once, as can be done by nut C increases the speed

connected in parallel and without load, each engine runs at 300 r.p.m. When the load is thrown on, one engine slows down to 294 r.p.m. and the other speeds up to 306 r.p.m. What is wrong and how would you remedy the trouble?"

It is my opinion that the engine which speeds up from 300 to 306 r.p.m. has responded to the load but failed to again regain its proper governor position. In other words, the governor is binding. The fulcrum pin on this kind of an engine is an important part of the apparatus and if it is not properly taken care of, that is, cleaned and lubricated with a grease fitted for the job and free from resin or like material, it may bind and cause the engine to slightly overspeed when the load comes on and the valve moves to give a longer stroke. By sticking, the lever will not regain its proper position after the increase in speed.

Again, as shown by the sketch, there is a knife edge where the springs hook on to the inertia end of the governor. The edge may be broken or damaged which will cause the lever to be slow in resetting. A over tight stuffing box on the valve stem will also have a tendency to shorten the valve stroke and cause sluggish action.

If the engines were mine I would take off the springs, disconnect the link from the governor lever to the eccentric or overhanging pin and pull off the lever. The engine that drops from 300 to 294 r.p.m. is sluggish in action, unless it is much overloaded. Probably this governor will also stand cleaning. When that type of governor is clean and well lubricated and has a tendency to be logey, a little more weight in the inertia end and tighter springs may liven it up but it should operate on less than 6 r.p.m. or 2 per cent speed change.

ZENAS ALLEN.

Wind Pressure on High Stacks

ASSUMING that there is no wind pressure, the stress existing in a stack is that due to the weight of material. In designing stacks, however, a 100 mile per hour wind must be assumed and the stack supported to resist the effective pressure resulting therefrom.

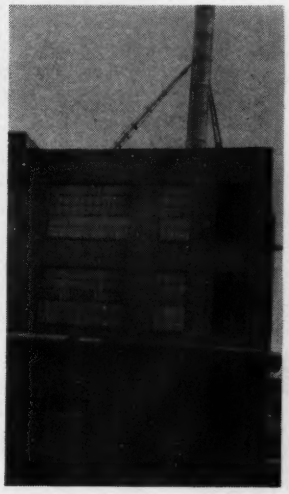
Considerable controversy exists as to the effective pressure produced by the wind on a cylindrical column. Most authorities agree that, taking the unit pressure exerted by the wind on a flat surface as 1 then for a cylindrical stack the effective unit pressure would be 0.5. In other words if we take a unit pressure of 50 lb. per sq. ft. as corresponding to a wind velocity of 100 miles per hour then the equivalent unit pressure for a round stack would be 25 lb. per sq. ft. of projected area. That this figure seems to provide ample factor of safety is evident by the number of stacks designed with this figure as a basis that have stood for long periods of time.

Stacks may be braced, as shown in the photograph Fig. 1, they may be guyed as shown in Fig. 2 or they may be designed self supporting. In the case of Fig. 1 the engineer used the bracing method shown because his building was located on the corner of the property and he had no place for an anchor on the other two sides. When this type of bracing is used the design must follow the self supporting method somewhat since the stack has no support near its top. The self supporting formula usually used is given by Gebhardt in his book Steam Power Plant Engineering, as follows:

$S' = Ph/0.8\ dt.$

In which S' is the stress per lineal inch in pounds; P is the height of stack above the point considered; d is the diameter of the stack; t is the thickness of the steel plates in inches; h is the moment arm which is height of stack above point considered times 12 times unit pressure caused by the wind or 25.

For the stack shown in Fig. 1 the section of stack above the point of bracing must be calculated as self supporting. That portion below the point of bracing must be figured for the bending moment taking the point of bracing as the axis or pivotal point and also for the stress caused by the weight of the stack. The larger of these two figures would be used in designing the plate thickness.



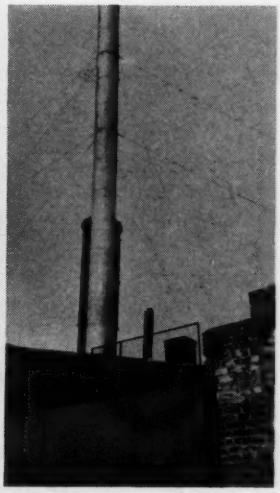


Fig. 1. Stack supported by braces
Fig. 2. Guy wires may be used where anchor points are available

For a guyed stack the thickness of the shell must be such as will support the accumulated weight above the point considered. The guys must be designed to withstand the resulting wind pressure. The point of attachment of the guy wires must be such as will withstand the wind pressure plus the unbalanced weight of the stack should there be sufficient sway at any time to permit the top of the stack to sway beyond the center of gravity.

Philadelphia, Pa. C. C. HERMANN.

Modern Utility Stations

IN the second installment of Philips Sporn's article on the American Gas & Electric Corp., which began on page 304 of the May issue, tabulated data on Windsor and Twin Branch Stations were transposed. Data in Table II is for Twin Branch not Windsor Station and data in Table III is for Windsor and not Twin Branch. Copies of the May issue should be corrected by transposing the two names in the first line of the captions for Tables II and III.

New Equipment

Information that you desire about any equipment will be gladly furnished without obligation. WRITE POWER PLANT ENGINEERING.

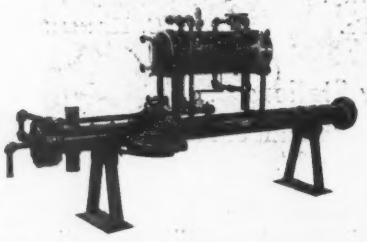
Pressure Indicator

A NEW TYPE of pressure indicator, for measuring the peak pressure in internal combustion engines or other machines in which pressures occur in successive cycles of the same form, has been developed by the Bachrach Industrial Instrument Co., Philadelphia, Pa. The essential parts of the indicator are a piston exposed to the engine pressure, a helical tension spring against which the piston acts and the tension of which is adjustable, and a neon light circuit with a contact switch operated by the piston so as to indicate any movement of the latter.

For making a measurement, the only operation required is to rotate the large, easy-grip, vulcanite ring nut located below the scales until the neon light stops flickering. This indicates that the spring tension is just sufficient to balance the maximum cylinder pressure which can be read off directly from the scales. The standard model reads up to 1200 lb. per sq. in.

Unit Blowdown System

THE HENSZEY CO., Watertown, Wis., announces the development of a new blowdown system, which built as a complete unit leaves only the piping connections to be made on the job. The new



unit consists of a flash tank solidly mounted on a heat exchanger. The blowdown flashing into the tank is automatically controlled and being proportioned to the makeup, keeps the boiler concentration at a predetermined value.

Vertical Welder

THIS 150-AMP. vertical type welder is designed to occupy a minimum of floor space, yet be available for a wide range of work. It has plug-in type cable receptacles for easy current reversing, and patented, single-current control. Furnished in a.c. drive only, with towing

handle for easy movement. Proper ventilation and cooling is provided through the fresh air intake at the top, and the exhaust at the bottom. It can also be furnished with lifting ring and without wheels where portability is not necessary. Harnischfeger Corp., Milwaukee, Wis.

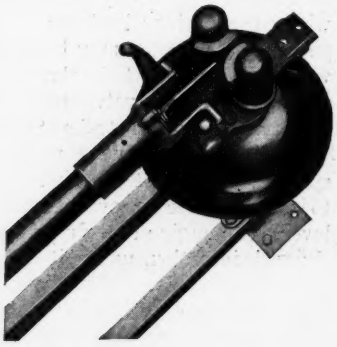
Duo-Motion Outdoor Air Switch

A NEW outdoor high-voltage group-operated air switch embodying a design which permits contact release before the blade is lifted is announced by the General Electric Company. The new switch has been termed the type RD "duo-motion" switch because of its method of operation in which the blade tongue is withdrawn by a horizontal movement, thereby releasing the pressure contacts, after which the blade is lifted vertically to the full open position.

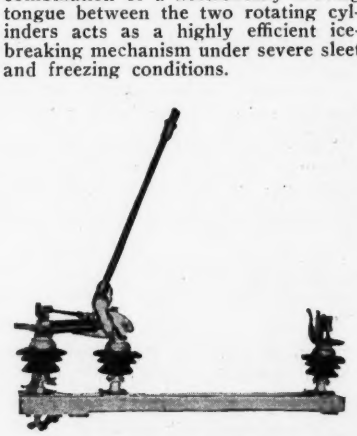
This dual motion of the blade in the opening or closing operation is a distinguishing feature of the RD-1 switch. The blade member consists of a tube through which passes a push-rod and a conductor terminating in a movable tongue. After the tubular blade has completed its downward travel in closing, the movable tongue is pushed outward in a horizontal movement to make intimate contact with two rotating cylinders with contact sectors.

In the closing or opening of the switch, a rotating stack of insulators operating in one continuous motion insures that the cranks will rotate in the proper sequence for extending or withdrawing the tongue at the proper time. An ingenious interlocking arrangement prevents the movement of this blade-tongue unless the tubular blade is at rest in the lowered position.

As the forward movement of the



tongue is slightly greater than the linear rotation of the contact sectors, it slides by the sector surfaces at the last movement, creating a wiping action which cleans the contact. The combination of a horizontally moving tongue between the two rotating cylinders acts as a highly efficient ice-breaking mechanism under severe sleet and freezing conditions.



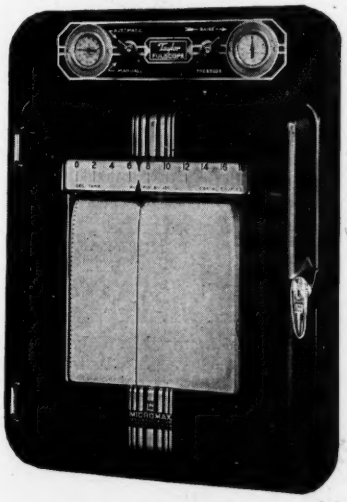
An alinement guide on the contact casting of the RD-1 switch serves not only as a guide to seat the blade properly but also eliminates any tendency of the protruding tongue to push over the stack by cantilever force during the closing operation.

Silver-to-silver contacts and an all-copper current-carrying path, common with all other G-E outdoor switches, are other features of the RD-1.

The RD-1 switch may be manually or electrically operated and is supplied for both disconnecting and horn-gap service, for voltages of 115 kv. to 230 kv.

Manual By-pass

In the November, 1937, issue of Power Plant Engineering the Taylor Instrument Co's. Fulscope Micromax Controller was described. A new feature, the manual By-pass, has recently been added to the instrument to enable the operator to change from manual to automatic control, or, vice versa, by a simple turn of the adjusting knob.

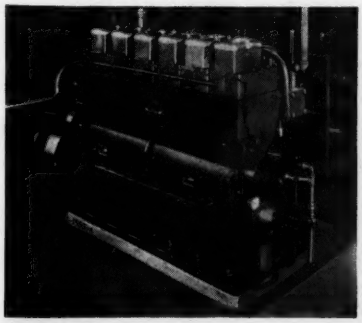


When the left adjusting knob on the instrument sub-panel is turned to the arrow marked Automatic, a 4-way air valve on the back of the panel connects the air supply to the Fulscope control mechanism. When the knob is turned to the arrow marked Manual, the 4-way valve connects the air supply directly to the diaphragm valve (or Dubl-Response Control Unit, as the case may be), by-passing the Fulscope mechanism.

The right adjusting knob regulates the air supply pressure, being connected directly to an air reducing valve on the back of the panel. When on automatic control the air supply is maintained at 25 lb. Before changing over from automatic to manual control, the output air pressure to the diaphragm valve is observed (left air gage) and the air supply (right air gage) is reduced to that valve.

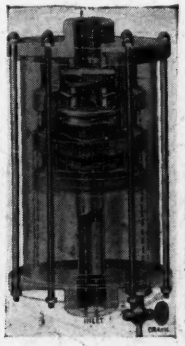
Vertical Four-Cycle Gas Engines

Developed to meet the increasing demand for a heavy-duty, moderate-speed, conservatively rated small gas engine, the Worthington Pump and Machinery Corp., Harrison, N. J., announces its vertical, four-cycle, type AG gas engine. It is designed particularly for power users where natural, manufactured, sewage or refinery gas is available. The outstanding features of the AG gas engine are valve-in-head construction, total enclosure of all moving parts, removable cylinder liners, separate water-cooled cylinder heads, light-weight, oil-tight covers for crankcase accessibility, and complete force-feed lubrication.



Hager Separator

The Hager Separator, designed to eliminate all possibility of pollution and remove all water, oil and dirt from compressed air, gas and steam at point of use, is now being made by Textite Corp., 2110 Roscoe St., Chicago, Ill. Measuring only 10½ in. high by 6 in. in dia. and weighing only 15½ lb., the separator is suitable for pipe sizes to ¾ in. Cleaning separation is obtained by linear deflection, jetting, centrifugal force, capillary attraction and sudden expansion. Mounted one above the other in this new separator are three internal vaned units through which the air, gas or steam must travel in succession before it can issue at the top connection.



Each of these units sets up a rapid whirling movement in the element as long as there is passage through the separator. The whirling throws moisture and dirt outward from the center. At the same time the flow is caught by additional sets of vanes curved in the opposite direction and secured to overlapping sleeves inside the housing. The reversal following the centrifugal action causes the moisture and dirt to strike the inner surface of the cups from where they drop to a collection chamber just inside the shell of the assembly. Flow from outlet is clean and dry.

Portable Potentiometer

The Wheelco Instruments Co., 1933 South Halsted St., Chicago, Ill., offers a new portable potentiometer specially designed and built for use in field or laboratory service.

This precision instrument is built in three different models: Model 310—with cold junction compensator; Model 320—with cold junction compensator and run-up box; Model 330—with cold junction compensator, run-up box, and standard thermocouple line compensating rheostat.

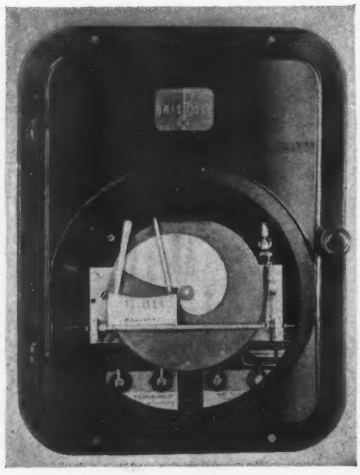
When used with thermocouples, this unit becomes a checking instrument, whose accuracy and sensitivity is far higher than any direct reading pyrometer. Standardized with regulation standard cell, and is equipped with precision slide wires and multipliers. Galvanometer is of regulation dual taut suspension type, complete with lock and zero adjuster. Scales are obtainable calibrated in millivolts or in degrees Fahrenheit or Centigrade, or both.

Capacitor for P.F. Correction

The engineering laboratories of the Cornell-Dubilier Electric Corporation, South Plainfield, New Jersey, announce the release of a new capacitor design for power factor correction on distribution systems. This capacitor is designed and constructed to operate out-of-doors under all climatic conditions. Completely enclosed in a non-corrosive metal cabinet, with special dustproof buss compartment, this unit lends itself admirably for platform or pole mounting. The capacitor for power-factor correction pictured here is a 180 Kv-a., 4,000 v., 3 phase, 60 cycle pole mounting unit.

Instrument for Telemetering Electrical Units

Electrical units—such as, volts, amperes, watts—are accurately measured and transmitted to a remote point by means of Bristol's Metameter. New features included in the design of these instruments have made it practical to apply this system of telemetering to electrical measurements, using standard measuring elements. They have now been adapted to measuring and telemetering electrical measurements of all magnitudes—from small millivoltages up to the totalized power output of power plants.



The principle involved has been used for a number of years by The Bristol Co. in transmitting readings of pressure, temperature, flow, mechanical motion, etc., from a transmitter at the point of measurement to a receiver, which is a recording or indicating instrument, at some distance away—a few feet or many miles. A cam, driven by a constant-speed motor gives the electrical impulses required to operate the system. This device is designed so that as it periodically engages and releases the pointer arm of the measuring element, no strain is placed on the element.

Overload Relay

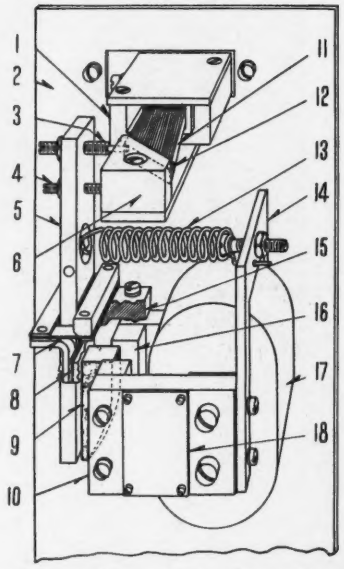
STRUTHERS DUNN, INC., Philadelphia, Pa., have recently developed a new overload relay. This unit is available for use on either d-c or a-c. The contacts are rated 30 amp. at 110 v. a-c, 20 amp. at 220 v. a-c, 6 amp. at 110 v. d-c and 3 amp. at 230 v. d-c on non-inductive loads.

This relay is somewhat similar to their line of mechanical latch-in electrical reset relays. The contacts can be arranged to be closed manually or by means of a voltage operated coil and when closed, they latch closed. The latch is adjusted to pick up and open the contacts when the current in the overload coil reaches the proper value. This setting is adjustable by means of the knurled nut on the top of the relay over a range of 2 to 1.

Silverstat Voltage Regulator For AC and DC Generators

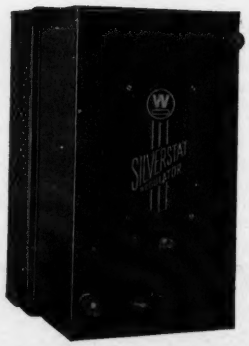
A SIMPLE, MODERATELY priced "Silverstat" regulator in a range of sizes for the automatic voltage control of small a-c and d-c generators is announced by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

The new regulator is of the direct and quick acting, rheostatic type and regulates the voltage by varying directly the resistance in the field circuit. The regulating action is that of a semi-static device which operates only when a correction in voltage is necessary.



The device consists of a voltage-sensitive stationary coil energized from the machine whose voltage is to be regulated. An iron magnetic circuit, having an air gap, mounts this coil. A moving arm is mounted so that an iron armature on its lower end can move, against the pull of a spring, in the air gap, under control of the stationary coil. Depending on the direction of its movement, the top end of the moving arm directly controls the closing or opening in succession of a series of silver buttons. Each silver button is mounted at the free end of an individual leaf spring, the other end being fixed. The silver buttons are wired in sequence, by connections from the fixed ends of the leaf springs, to consecutive steps of a stationary regulating resistance.

The regulating resistance is connected directly in the field circuit (exciter shunt field in a-c applications and generator shunt field for self-excited d-c generators). Thus, as the moving arm operates over its travel, it successively opens or closes the silver buttons to directly increase or decrease the resistance in

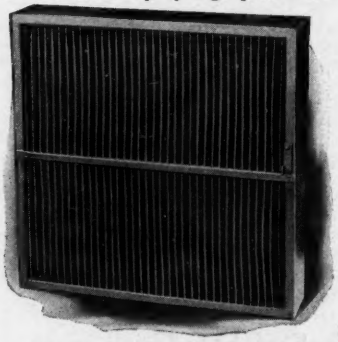


the field circuit. For a given value of regulated voltage and load on the machine being regulated there is a corresponding value of regulating resistance required in the field circuit. To give this value of resistance there is a corresponding position of the moving arm and silver buttons, and the moving arm takes a balanced position at that point in its travel.

Dry Type Air Filter

RECENTLY announced by Staynew Filter Corp., Rochester, N. Y., is a new dry type air filter possessing unusual advantages for industrial and domestic air conditioning. Known as the Wire-Klad, the new filter is flame-resistant, which fulfills the provisions set forth in Section 150 of the National Board of Fire Underwriters.

The fin construction, a well-known Protectomotor principle, affords large filtering area in relatively small space. The wire mesh reinforces the filtering medium so strongly that the filter can be cleaned indefinitely by high pressure air

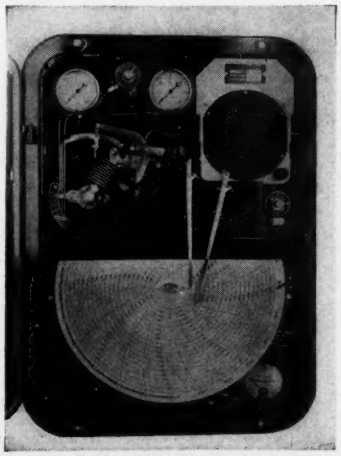


or vacuum. Several kinds of filtering media to suit varying conditions are available. The most usual are cotton or a wool felt-like material known as Feltex. This latter medium is practically impervious to the passage of even microscopic dust particles, yet offers extremely low resistance to air flow. If exposure to oil or greasy substances makes cleaning with a solvent necessary, the wire reinforced filter insert can be easily lifted from the frame. Besides low initial cost and easy cleaning, this new filter also possesses the advantage of low replacement cost when finally worn out, as wire reinforced filter insert only need be replaced.

Standard and special sizes are available. There are three standard depths—2, 4 and 6 in., and four standard sizes—20 by 20 in., 16 by 20 in., 16 by 25 in. and 20 by 25 in. With the thought in mind that many installations require special sizes, these will be furnished at no extra cost if within reasonable limits.

Potentiometer Controller

A NEW RESET POTENTIOMETER CONTROLLER for continuous processes, combining Bristol's Pyromaster Potentiometer temperature measuring system and Bristol's Reset Free-Vane air-operated control mechanism, has been announced by The Bristol Co., Waterbury, Conn. This instrument, known as Bristol's Pyromaster Reset Potentiometer Controller can be used for automatically controlling temperatures up to 3000 deg. F. and is offered as a Pyrometer and also as a Resistance Thermometer. A record of the controlled temperature is made on a 12-in. circular chart.

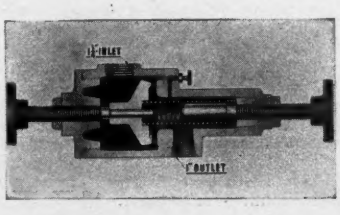


The Reset Control mechanism operates on the basic Free-Vane principle of air-operated control. As the name implies, there is no retarding action at any point on the scale. The measuring system is free to measure and record the true temperature above, below, and at the control point. This is possible, because due to the unique design employed, practically no power is required from the measuring element to operate the control apparatus.

In the Pyromaster Reset Potentiometer Controller certain features of field adjustability have been added, whereby the throttling range and rate of reset may be changed over a wide scope by the user through simple finger adjustments to suit the requirements of the process involved.

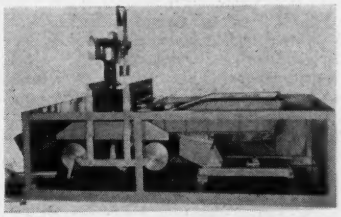
Automatic Shut-Off Valve

DESIGNED as a safety appliance to promote the efficient use of tools wherever flexible hose is used, the D. J. Murray Mfg. Co., Wausau, Wis., is now manufacturing an automatic shut-off valve sold under the trade name, Murray-Lorge, which immediately shuts off the supply when there is a break in the hose or it becomes disconnected. Operating on the principle of equalization, the plunger is maintained in an open position by a spring as long as the pressure at the inlet and outlet are nearly or exactly the same. This permits the air, steam or other supply to flow around it in a normal manner. The plunger may be adjusted to shut off automatically the flow at any desired pressure at the inlet or sizes of break at or below the outlet.



Weigh Coal Feeder

SYNTRON Co., 494 Lexington Ave., Homer City, Pa., has just placed on the market a new, accurate, automatically scale-controlled feeder for feeding coal by weight control. It is made up of a constant speed belt conveyor driven by a synchronous motor. The entire belt conveyor assembly is suspended from a sensitive scale which is equipped with electric valves actuated by the slightest underweight or overweight movement of the scale beam. The material is fed to the belt conveyor by a Vibra-Flow Feeder Conveyor by vibration, the trough being mounted on springs and reciprocated by a pulsating electro-magnet.



The rate of flow of material through the Vibra-Flow feeder trough is controlled by varying the power or energy to the trough's driving electro-magnet and this control of the power or energy to this electro-magnet is through the sensitive electric valves on the scale, which speed up the flow when the load on the belt conveyor gets underweight or slows it down when the load on the belt gets overweight, maintaining automatically an accurate constant load on the constant speed belt conveyor.

The coal is fed into the Vibra-Flow feeder trough through a 12 by 12 in. chute coming down at a 45 deg. angle from a storage supply hopper above. These machines are available in various sizes ranging in capacity from a few pounds per hour up to tons per hour.

New Self-Alining Belt Idler

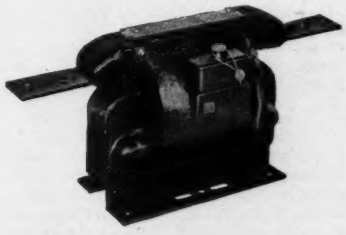
A NEW self-alining idler for automatically training conveyor belts without damaging the belt is announced by The Jeffrey Mfg. Co., Columbus, O. It consists of a standard anti-friction idler pivotally mounted on a supporting cross member, with guide rolls at each end. These guide rolls are mounted on pivoted arms that extend at right angles to the idler in the direction from which the belt approaches. The arms are held in

place by an easily removed locking pin. Merely by swinging the arms through 180 deg. and putting the lock pin in place on the opposite side, the guides are made ready to train the belt when traveling in the reverse direction. As there is no pressure between the guide rolls and belt, there can be no damage to the edge of the belt. The guide roll moves outwardly the instant the belt touches it, and in so doing swivels the idler sufficiently to cause the belt to return to normal position.

5000-V. Indoor Current Transformer

GREATER ACCURACY, higher insulating qualities, and finer construction are features claimed for the new type JW-1, 5000-v. indoor current transformer developed by the General Electric Co. The new product replaces the WF-12 in the company's transformer line.

Use of a newly developed high-permeability steel and the patented Wilson scheme of compensation in the JW-1, combined with close manufacturing control, and narrower test limits, make for greater uniformity in the new transformer. Ratio and phase-angle errors are reduced to a point where they may be disregarded for even the highest grade of metering. Accuracy of the new JW-1 conforms to the highest NEMA rating of ¼X, ¼Y, and ¼Z at 60 cycles.



The insulation strength of the JW-1 transformer amply meets the requirements for the normal standard insulation level for the 5000-v. class. On impulse voltages, with a 1.5 × 40 microsecond wave, the insulation is equivalent to the 2.2-in. test gap. It is given the standard factory test of 19 kv. on 60 cycles.

The improvements in accuracy and insulation of the new JW-1 have been made without increasing its size and the new transformer is interchangeable with the WF-12. Mounting dimensions, overall length, spacing of primary terminal bolt holes, and height of primary terminals are identical in the two types. Overall height in ratings up to 300 amp. has been increased only ⅛ in., and in the larger ratings only ⅜ in. Overall width in ratings up to 300 amp. has been increased ¼ in., while units of larger ratings remain unchanged in this respect.

News from the Field

R. C. VAUGHN, who has had over 20 yr. experience in the sales of electric hoists and overhead traveling cranes in the New York area, will join the New York office of The Harnischfeger Corporation as Sales Engineer.

ON APRIL 23, the Chicago offices of Burgess Battery Co., Burgess Cellulose Co., Burgess-Parr Co. and C. F. Burgess Laboratories, Inc., were moved to 500 West Huron St., Chicago, Ill.

LEWIS H. BROWN, president of Johns-Manville Corp., has announced the organization of a Virginia subsidiary which has acquired 142 acres of land near Jarratt, Virginia, on which it will start immediately to erect a new factory for the manufacture of insulating board products. This will require expenditure of over a million dollars, the new factory being of capacity to employ between 300 and 400 persons, with a small experienced staff from other J-M plants to supervise and train the local plant personnel.

T. E. Reese will be Johns-Manville representative at this new location; and R. F. Bower will organize a wood procurement program, as large quantities of southern pine will be used to provide the wood pulp.

A. K. HOWELL Co. has been appointed as St. Louis representative of Troy Engine and Machine Co. of Troy, Pa., in place of F. E. Bausch, recently deceased.

J. N. GOODIER, who holds the degrees of Ph. D. from Cambridge University, England, and Sc. D. from the University of Michigan, has been named acting professor of mechanics in the Sibley School of Mechanical Engineering at Cornell University, President Edmund E. Day has announced. Widely known for his research in elasticity, plasticity, and advanced dynamics, Dr. Goodier comes to Cornell from the Ontario Research Foundation, where he has been research fellow in applied mechanics since 1931.

CHARLES H. SHAW, for the past 3 yr. Philadelphia Office Manager for the Worthington Pump and Machinery Corporation, died at his home on April 15, 1938. Mr. Shaw was associated with Worthington since 1920, and was manager of the corporation's Pittsburgh office from 1928 to 1935.

He was born in Owensboro, Kentucky, in 1898, and graduated from Syracuse University in 1919. Since that time, as a member of the Worthington organization, he served the corporation on several important assignments.

WILLIAM ARTHUR has been appointed Philadelphia District Office Manager of Allis-Chalmers Mfg. Company to succeed the late J. E. Wray. Mr. Arthur since 1931 had been the Company's Special Representative for railway traction and mercury arc rectifiers in the East, attached to their New York and Philadelphia Offices.

NORTON COMPANY of Worcester, Mass., announces the appointment of Milton P. Higgins as Resident Manager of the Chippewa, Ontario, electric furnace plant, the position held by the late John B. Glaze. Mr. Higgins, who will assume his new duties about May 15, 1938, has been with the Company about ten years and has had experience in both sales and production. Lately he has been Manager of Sales Research. He is also a member of the Board of Directors of the Norton Company.

ARLEN "ZACK" JENNINGS has recently been appointed chief engineer of Walter Bledsoe & Co., wholesale coal dealer. He will maintain headquarters in Chicago.

THE MARLEY CO. opened its Southeastern sales branch in Atlanta, Ga., during the last week in April. T. A. Tobin, formerly of the home office sales staff in Kansas City, is in charge of the new office located in the Walton Building.

CHARLES H. BLISS has been elected president of American Utilities Service Corp., 231 South La Salle St., Chicago, Ill., succeeding Perry Crawford who has resigned to become vice president of Central Service Corporation, both positions effective May 1, 1938.

Mr. Bliss, who for the past twenty-two years has been president in charge of the Chicago division of E. H. Rollins & Sons, Inc. has been succeeded by Perry Dryden formerly vice president. Central Service Corp., public utility consultants, will render advisory and other services to American Utilities Service Corp. and subsidiary companies after May 1, 1938.

JOSEPH B. FOWLER, 49, Special Field Engineer of the Cochrane Corp., Philadelphia, Pa., died suddenly of a heart attack on April 15, 1938. Mr. Fowler, during his association with the Cochrane Corporation for the past 25 years, was responsible for many major developments and design improvements in the field of feedwater conditioning, deaeration and steam purification.

IRVING E. MOULTROP, formerly chief engineer of the Boston Edison Co., was reelected Chairman of the Advisory Committee of the Thirteenth National Exposition of Power and Mechanical Engineering at a meeting of the Committee held in New York on May 5. Plans for the Exposition, which will be held at Grand Central Palace in New York, December 5 to 10, were discussed, and as a result several new features will enhance the value of this year's showing over past successful presentations. John H. Lawrence of Interborough Rapid Transit Co. was elected Vice-Chairman of the Committee. Other members include Homer Addams, Past President, American Society of Heating and Ventilating Engineers; Fred Felderman, Past National President, National Association of Power Engineers; C. F. Hirschfeld, Chief, Research Department, Detroit Edison Co.; David Moffatt Myers, Consulting Engineer; Arthur L. Rice, Editorial Director, "Power Plant Engineering"; P. W. Swain, Editor, "Power"; and Charles F. Roth, Manager of the Exposition. A number of new members were nominated and their names will be announced shortly.

AT THE ANNUAL meeting of the National Association of Fan Manufacturers, the following men were elected officers for the ensuing year: C. T. Morse, President; R. R. Ware, Vice-President; L. O. Monroe, Secretary-Treasurer. The Association now entering its twenty-second year of continuous existence retains on its roster practically the same manufacturers who founded it. The membership includes the American Blower Corp., Autovent Fan & Blower Co., Bayley Blower Co., Buffalo Forge Co., Clarage Fan Co., Garden City Fan Co., The Green Fuel Economizer Co., Inc., Ilg Electric Ventilating Co., The New York Blower Co. and B. F. Sturtevant Co.

CHESTER C. SMITH, of the Kansas City Power & Light Co. was re-elected president of the Missouri Association of Public Utilities at its annual convention in St. Louis recently. E. A. Beer, Jefferson City, was re-named managing director.

BRUNO RAHN, vice president and general manager of the Milwaukee Gas Light Co. was recently elected president of the Wisconsin Utilities Association. Also elected were A. P. Gale, executive vice president of the Wisconsin Power & Light Co., vice president, and John Dockendorf, assistant research engineer of the Milwaukee Electric Railway & Light Co., treasurer.

PUBLIC SERVICE ELECTRIC & GAS CO., Newark, N. J., recently announced the following appointments in the electric department:

Walker L. Cisler, assistant chief engineer; William R. Smith, safety engineer; Fred H. Legge, transmission construction engineer; Walter C. Ames, chief engineer of the Marion generating station; Leslie D. Price, meter and wiring engineer.

VIRGINIA ELECTRIC & POWER CO's. 1938 improvement program includes $650,000 for improvements to power stations, transmission lines, and distributing system; $140,000 to rebuild the high tension line between Richmond and Petersburg; $1,250,000 for extensions to connect new customers; and $175,000 for construction of rural lines.

THE COCHRANE CORP., Philadelphia, Pa., announces the appointment of C. J. Gaskell Co., 1011 Falls Building, Memphis, Tenn., as district representative for all of its products in Arkansas, western Tennessee and northern Mississippi.

THE SHEFFLER-GROSS CO., Drexel Bldg., Philadelphia, Pa., have been appointed representatives for eastern Pennsylvania by the American District Steam Co., North Tonawanda, N. Y.

Edgar W. Wagenseil

EDGAR WHITE WAGENSEIL, Sales Manager of Hagan Corporation, and a resident of Oakmont, Pittsburgh, died suddenly Tuesday afternoon, May 10, while engaged in his official duties. He was 54 yr. old.

Mr. Wagenseil was born at Port Huron, Michigan, in 1884. He was graduated from the University of Illinois in 1905, and was first employed by Illinois Steel Co. as steam engineer at their South Works plant.

He was later associated with the Chicago Smoke Abatement Commission and with the Burke Furnace Co., manufacturers of furnaces and stokers.

During the World War, Mr. Wagenseil was an officer in the Aviation Division of the U. S. Navy Department. Following the war he was connected successively with the Harrington Stoker Co., Westinghouse Co., and later with Blaw-Knox, where he was engaged for 5 yr. in selling preheaters in the steel industry.

For the past 6 yr. Mr. Wagenseil has been General Sales Manager of Hagan Corporation and its subsidiaries, The Buromin Co. and Hall Laboratories, Inc. He was a member of the American Society of Mechanical Engineers, the Engineers' Society of Western Pennsylvania, and the Pittsburgh Field Club.

Seminoe Dam Power Rates

TENTATIVE RATES for the sale of power to be generated at Seminoe Dam, where the installation will have a capacity of 45,000 hp., have recently been announced. Seminoe Dam, the major engineering structure of the Kendrick Federal Reclamation Project in Wyoming, will be completed in 1939. It will store in excess of 1,000,000 acre-feet of water for irrigation, regulation of the North Platte River, and for power, and will make possible the diversion at Alcova Dam, recently completed by the Bureau of Reclamation, of sufficient water for the irrigation of 35,000 acres of desert lands in the vicinity of Casper, Wyo.

A. S. H. & V. E.

FOR THE SUMMER MEETING of the American Society of Heating and Ventilating Engineers, to be held at The Homestead, Hot Springs, Va., June 20 to 22, the tentative program just announced, lists ten technical papers and an extensive program of entertainment.

The Council of the Society will hold its semi-annual meeting on June 19. A meeting of the Society's Committee on Research will be held in connection with the technical sessions and the banquet and dance will take place on the evening of June 21.

Papers scheduled for presentation and discussion are as follows: A Test Method for Air Cleaning, by R. S. Dill; The Flow of Air Through Exhaust Grilles, by A. M. Greene, Jr., and M. H. Dean; The Condensation Nuclei Content of the Air as Related to Air Freshness, by R. A. Nielsen; Heat Transfer Through Single and Double Glazing, by M. L. Carr, R. A. Miller, Leighton Orr and Alan C. Byers; Glass Heat Transfer Coefficients, by D. Shore; Performance of Surface Coil Dehumidifiers for Comfort Air Conditioning, by G. L. Tuve and L. T. Seigel; Seasonal Variations in Effective Temperature Requirements, by F. E. Giesecke, W. H. Badgett and F. C. Houghten; Cooling Requirements for Summer Comfort Air Conditioning in Toronto, by C. Tasker; The General Reactions of 275 Workers to Summer Cooling and Air Conditioning, by A. B. Newton and F. C. Houghten; Study of Summer Cooling in the Research Residence using a Small Capacity Mechanical Condensing Unit, by A. P. Kratz, S. Konzo, M. K. Fahnestock and E. L. Broderick.

W. C. Unwin Memorial

DR. W. C. UNWIN, a leading authority on hydraulics, pneumatics, steam power engineering and other branches of engineering, as well as a distinguished educator, whose textbooks have aided many engineering students in starting their careers, was widely honored by degrees and with official positions during his lifetime. The Kelvin Medal, highest honor of the British engineering world, was his.

Since his death in 1933 his friends, associates and past students have been engaged in creating a memorial by raising funds to endow an Unwin Scholarship in the Central Technical College of London, Eng., and the American Society of Mechanical Engineers and American Society of Civil Engineers of which Dr. Unwin was an honorary member, are participating in this effort. Many will, no doubt, be glad of the opportunity to join in this testimonial to Dr. Unwin and the Unwin Memorial Committee will be gratified to receive any contributions, which may be sent to E. G. Walker, Honorary Treasurer, 82 Victoria St., London S. W. 1, England.

New President for American-Marsh Pumps, Inc.

ELMER M. JENKINS was elected President and General Manager of American-Marsh Pumps, Inc., Battle Creek, Mich., at the April meeting of the Board of Directors. Mr. Jenkins, a West Point graduate, is a man of wide experience in selling, merchandising and administrative affairs. He succeeds Richard R. Hicks, who was president of the company for more than twenty years. Mr. Hicks retains his position as a member of the Board of Directors.

From the time the company was organized in 1873 until last year, American-Marsh Pumps, Inc., was known as the American Steam Pump Co. The change in name was effected to describe more adequately the complete line of pumps now manufactured. Today this company builds practically every approved type for almost every class of service—steam, power, centrifugal, turbine and fire pumps, and shallow and deep well water systems.

Research Fellowship Appointments Announced

THE FIRST five Westinghouse Research Fellows have been selected for work in fundamental science at the Westinghouse Research Laboratories in East Pittsburgh. The successful candidates chosen from a group of 50 are:

ROBERT O. HAXBY, University of Minnesota. Mr. Haxby, whose home is in Minneapolis, is 26 has received the bachelor's and master's degrees in electrical engineering from the University of Minnesota. He has been a graduate student in physics there for the last four years and has participated actively in the nuclear physics research there.

JOHN A. HIPPLE, Princeton University. Mr. Hipple is 27. His home is in Lancaster, Pa., where he received a bachelor's degree in physics from Franklin and Marshall College. He has been a graduate student in physics at Princeton during the past 4 yr. where he has worked with Prof. Walker Bleakney and where he expects to receive the degree of doctor of philosophy in June.

SIDNEY SIEGEL, Columbia University. Dr. Siegel is 26 and received his doctor's degree 2 yr. ago for researches on elastic and magnetic properties of metals carried out under the direction of Prof. S. L. Quimby. Dr. Siegel is a native of New York City, and received his bachelor's degree in 1932 from Columbia College. Dr. Siegel will continue his studies on fundamental properties of metals.

W. E. SHOUPP, University of Illinois. Dr. Shoupp is at present an instructor in physics at the University of Illinois, where he is actively engaged in studies on nuclear physics, with the Illinois cyclotron. Dr. Shoupp is 30, and his home is in Troy, Ohio. He received his bachelor's degree from Miami University, Oxford, Ohio, and went to Illinois for graduate study in 1931.

W. E. STEPHENS, California Institute of Technology. Stephens is 26, and expects to receive the doctor's degree next June for researches in nuclear physics conducted in the Kellogg Radiation Laboratory in Pasadena. While in Pasadena, he has collaborated with Professor C. C. Lauritsen. He is a native of St. Louis, Missouri, where he received a bachelor's degree in 1932 and a master's degree in 1934 from Washington University. At Washington University he did researches on focusing of ion and electron beams in collaboration with Prof. A. L. Hughes. In Pasadena, Stephens has studied the production of neutrons by bombarding boron and nitrogen with high energy deuterons. He has also worked on the development of a new type of high voltage discharge tube.

Harry F. Boe, Manager Westinghouse Serv. Dept.

APPOINTMENT OF HARRY F. BOE as manager of the service department of The Westinghouse Electric & Manufacturing Company is announced by President George H. Bucher. He succeeds W. K. Dunlap, assistant to vice-president, formerly in charge of the department, who retires.

An Ohioan, whose birthplace was Mansfield, now an important Westinghouse manufacturing center, Mr. Boe started work at East Pittsburgh in 1900 as a coil winder, after previous experience in foundry, pattern and machine shops. He spent ten years on shop floors working as a winder, assembler and tester of electrical equipment. During these years, while working, he studied engineering at night at the Carnegie Institute of Technology. By 1910, he had been foreman of the testing division for several years and was ready for his next post in the engineering department. In 1916 he left the company but returned two years later to join the sales office in Rochester, N. Y. Since 1922, he has been, successively, manager of the Buffalo sales office; Eastern district manager, with headquarters in New York; and commercial manager, the position to which he was appointed in May, 1937 when he moved to Pittsburgh to make his headquarters here.

For the Engineer's Library

Any Catalogs that you wish will be gladly sent. Write Power Plant Engineering.

Instruments

Instrument Boards—A new 22-page bulletin describes standard practice in control board design. Illustrations throughout show typical layouts for instrument boards. A brief discussion of design and materials is followed by specific information on standard sizes of panel boards available in different materials, such as steel, slate, ebony asbestos wood and marble. Standard panels for mounting Foxboro instruments are shown, with installation data. For particular plant requirements, special mountings are described. Copies of this bulletin are available on request to The Foxboro Co., Foxboro, Mass.

Instrument Transformers—New instrument transformers that provide reliable metering at low cost are discussed in a 12-page illustrated booklet. Discussed are: Coördinated insulation, new wide-range accuracy on overcurrents through type FW current transformers, potential transformers giving double protection against impulse voltage, quick-change construction of base and terminals to simplify changing current transformers to meet varying loads, and meter box which houses two FW current transformers with watthour meter and socket on cover. Copies may be secured from Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Rotameters — A 24-page Bulletin 102 describes in detail the F. & P. precision-bore process and F. & P. rotameters with precision-bore tubes. Fischer and Porter Co., 110 West Penn St., Germantown, Philadelphia, Pa.

Recording Thermometers and Pressure Gages—A new 44-page bulletin describes in detail the Mason-Neilan line of pressure recorders and recording and indicating thermometers featuring the Floating Coil Movement and the Overheat Protector for vapor pressure thermometers. It contains much data to aid in the selection of the proper instrument for the job. Mason-Neilan Regulator Co., 1190 Adams St., Boston, Mass.

Portable Oil Testing Equipment—Field and truck type outfits for testing oil are summarized in an 8-page illustrated pamphlet. The dielectric strength of insulating oils in transformers, circuit-breakers, switches and any other oil insulated apparatus may be determined quickly and accurately by means of these portable instruments. The catalog also describes the operation of high-voltage testing equipment to be used in cable testing. A large kilovolt-ampere capacity transformer is required for such testing because of the high electrostatic capacity involved. Each type of equipment is illustrated and tables include list prices and styles. Copies may be secured from Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Socket Instruments — A 20-page booklet entitled Socket Instruments illustrating installations, applications and economies of these "plug-in" instruments, points out that the sockets are self-supporting and money saving devices. Ammeters, voltmeters, wattmeters, watthour meters, recorders, and test jacks may be conveniently plugged into these sockets. The test jack is supplied with cable leads for connection to conventional instruments or analyzers. These socket instruments provide accurate facts about power costs and equipment performance. The location of instruments is shown in a circuit diagram. A complete line of Westinghouse electrical instruments are shown, including portable instruments, medium switchboard instruments, large switchboard instruments and socket instruments. Copies may be secured from the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Pumps and Compressors

Water System Pumps — Dallas, Texas, after many emergencies in respect to water supply, now has behind the new Lake Dallas dam sufficient water for fire protection and for commercial and domestic use to outlast, it is estimated, 4 rainless years; also adequate distribution and pumping facilities. The history of this development is given in a pamphlet De Laval Pumps at Dallas, published by the De Laval Steam Turbine Co., Trenton, N. J.

Pumps—The Double-Suction, horizontally split type centrifugal pump is completely illustrated and described in Bulletin 201-2. Lawrence Machine and Pump Corp., 371 Market St., Lawrence, Mass.

Pumps—Four new bulletins describe and illustrate centrifugal and screw type pumps. Bulletin C-106-A is on multistage type; No. C-209 covers vertical centrifugals; No. C-213 is on pumps with case vertically split and end suction; No. S-104-A deals with construction and performance of rotary screw pumps. Quimby Pump Co., Newark, N. J.

Air Compressor—Single-stage horizontal compressors for heavy duty service with Timken bearings and Dual-Cushion valves in sizes 40 to 125 hp. for pressures 10 to 125 lb. are illustrated and described in Bulletin A-12-A of Sullivan Machinery Co., Michigan City, Ind.

End Suction Centrifugal Pumps is the subject of a new bulletin 7069, which presents pictures of several of these installations as well as complete tables of performances and dimensions, with explanations for selection of the proper size pump. Copy of Bulletin 7069 may be obtained from Ingersoll-Rand Co., Cameron Pump Division, 11 Broadway, New York, N. Y.

Water Treatment and Control

Water Treatment—A limited number of reprints are available without cost, on a paper entitled "Acid and Reactive Colloids for Cooling Water Treatment." This paper was prepared and presented by L. D. Betz, Chemical Engineer, before the Petroleum Section of the American Chemical Society at their sectional meeting in Okmulgee, Okla. Requests for copies and a list of other available literature should be directed to W. H. & L. D. Betz, 235 W. Wyoming Avenue, Philadelphia, Pa.

Water Control—Three new bulletins treating such subjects as continuous blowdown, boiler feedwater meter and flow indicator, illustrate and describe these subjects in regard to construction and operating features. Henszey Co., Watertown, Wis.

Water Treatment is the subject of a new Bulletin entitled Wide and Deep as the Grand Canyon which was recently issued by Hagan Corp., Pittsburgh, Pa.

Piping

Pipe Tools—The Beaver Model-B pipe and bolt machine is described and illustrated in a new bulletin. Another bulletin discusses tools used in threading and cutting pipe. Beaver Pipe Tools, Inc., Warren, Ohio.

Piping—Bulletin 200, entitled Corrugated Type Expansion Joints, describes and illustrates Badger nonequalizing, single and multiple corrugation, expansion joints, copper and stainless steel. Bulletin 300 describes the Badger Pipe line flexible seals. E. B. Badger & Sons Co., Boston, Mass. Mass.

Curtis Pipe Cutting and Threading Machines are described and illustrated in a 12-page catalog. It includes specifications for hand machines and belt-driven machines. Curtis and Curtis Co., Bridgeport, Conn.

The Inside Story of Crane Plug Disc Globe and Angle Valves is the subject of a new, 8-page, two-color booklet. Besides being profusely illustrated, there is a full page table which lists the essential characteristics of each member of the Crane plug disc family. Crane Co., 836 South Michigan Avenue, Chicago, Ill.

Materials

New Stress-Rupture Test Data—The value of the recently developed stress-rupture test in determining the high temperature characteristics of various steels is discussed in considerable detail in Technical Bulletin No. 21, just issued by The Steel and Tube Division of The Timken Roller Bearing Company. This 16-page bulletin is an authorized reprint of a paper presented by A. E. White and C. L. Clark of the Department of Engineering Research of the University of Michigan and W. G. Hildorf, Chief Metallurgist of The Timken Roller Bearing Co. Three tables and six photo-micrographs substantiate the discussion, which points out the practical and technical value of this test and its data to anyone interested in the design, operation or maintenance, or metallurgy connected with high temperature operations in oil refining, steam generation or similar processes. Copies of this new bulletin are available on request to The Steel and Tube Division of The Timken Roller Bearing Co., Canton, O.

Six Minutes with 6 Metals is the title of a 16-page folder describing briefly some of the uses for, physical properties of various corrosion resistant and oxidation resistant alloys made by The International Nickel Co., Inc., 67 Wall St., New York, N. Y.

How to Reduce Spalling with Super Duty Refractories—A new 12-page booklet so entitled has just been published. It is attractively printed in two colors and gives charts, tests, and general information on three types of super duty refractories—Hiac, Superac and Airam. General Refractories Co., Philadelphia, Pa.

Rooflex—A new roof material is the topic of discussion in a new 4-page bulletin which has recently been issued by the Flexrock Co., 800 N. Delaware Ave., Philadelphia, Pa.

Dyn-el—a new high-strength flat-rolled steel with unusual resistance to fatigue, impact and corrosion is described in a new book entitled "A. W. Presents DYN-EL." Alan Wood Steel Co., Conshohocken, Pa.

Plates and Tubular Products—Definitions and descriptions of carbon steel plates and steel tubular products are set forth in two pamphlets which comprise Sections 6 and 18 of the Steel Products Manual. The pamphlet on carbon steel plates classifies plates by size and by qualities, and describes standard and special manufacturing practices. Chemical limits and tolerances for thickness, flatness, camber, etc., are also included. The tubular products section gives definitions of standard pipe, oil country tubular goods, pressure pipe, pressure tubing and mechanical tubing, together with the manufacturing tolerances applying to each class. Single copies of any of the six sections now available for distribution can be secured from the American Iron and Steel Institute, 350 Fifth Ave., New York, N. Y., for 15 cents each.

The Care of Hot Water Tanks and Heating Coils is the title of a new bulletin which describes methods of cleaning hot water storage tanks and heating coils. It also discusses certain operating conditions that affect the life and the efficient operation of such equipment. Copies of this bulletin will be sent on request to Water Service Laboratories, Inc., 423 W. 126th St., New York, N. Y.

Filters

Norblo screen type dust arrester is described and illustrated in Bulletin 1002. It discusses the construction, operation and specifications. The Northern Blower Co., 6409 Barberton Ave., Cleveland, Ohio.

Air Filter—The new Permo flame proof throwaway type filter is described in detail in Bulletin P405-36 which has just been issued by the Independent Air Filter Co., Inc., 228 No. La Salle St., Chicago, Ill.

Welding

Pipe Welding—Arc welding of piping for operations at pressures up to 1500 lb. per sq. in. and temperatures up to 1000 deg. F. is covered in a new 12-page bulletin. In addition to the selection of pipe materials and welding electrodes, this bulletin discusses weld design, welding procedure, preheating, stress relieving, testing of welds and the qualification of welding process and welding operators. Metal & Thermit Corp., 120 Broadway, New York, N. Y.

Electrodes—A 12-page booklet has just been issued covering a new electrode called the Page Hi-Tensile G. This is a high speed smooth flowing electrode of the shielded arc type, suitable for use with either motor generator or transformer type machines and it is especially recommended for flat and positioned fillet and general flat welding. Page Steel and Wire Division, American Chain & Cable Co., Inc., Monessen, Pa.

Arc Welders—A new bulletin entitled 1000 Combinations describes and illustrates Hobart's new multi-range arc welder. The Hobart Brothers Co., Hobart Square, Troy, Ohio.

Packing

Packing—Three new bulletins, each containing a story every engineer should know, illustrate and describe 15 different types of packing. The bulletin entitled, Pistons Don't Pull Their Punches contains a chart to make the selection of Oil and Gasoline Service packings easier. A chart to make the selection of steam service packing easier is included in the bulletin entitled Is Your Horsepower Running Away? Selection of water service packing is made easier by the chart in the bulletin entitled Pressure Versus Packing. The Belmont Packing and Rubber Co., Butler and Sepviva St., Philadelphia, Pa.

Monel Gaskets—A new 8-page bulletin entitled New Life for Oil Equipment illustrates and describes Monel gaskets. The International Nickel Co., Inc., 67 Wall St., New York, N. Y.

Crane Packing—A 32-page book under this title approaches the proportions of a detailed guide for the installation of plumbing and heating equipment in industrial and commercial buildings. The book which is printed in two colors covers by word and picture such subjects as the importance of proper sanitation in industry, the dangers of back siphonage, typical installations, lavatories, faucets and fixtures for wash sinks, showers, drinking fountains, water closets, urinals, sinks and plumbing brass. Other subjects covered by the book include such industrial hospital equipment as lavatories, sinks and special hospital fixtures. In addition there are pages devoted to heating equipment such as boilers, radiators, convectors, speed heaters, heating accessories, also water treating equipment and water systems. Crane Co., 836 South Michigan Ave., Chicago, Ill.

Electrical Equipment

Stop Lightning's Costly Raids with C.S.P. Transformers is the title of a 12-page booklet. Included are discussions of the three major and three minor insulation points in every distribution transformer which must be protected against voltage that builds up against different parts of the transformer. It describes how the "de-ion" gap by-passes lightning surges, characteristics of the "de-ion" gap and the advantages of 3-point protection. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Electrical Equipment—A number of new bulletins under the following titles have been issued by General Electric Co.: Reconditioning Flooded Electric Equipment, GEA-2571B; Gear-Motors, GEA-1437C; Arc Welders, GEA-1440G; Type B Direct-current Motors, GEA-1542C; Magnetic Motor-starting Switches, GEA-2889; Wound-rotor A-c Crane Motors Type MR, GEA-2714; New Track-Type Limit Switch, GEA-2052A; Direct-current Generators and Exciters Type B, GEA-1607B; CR2931 Float Switches, GEA-67E. General Electric Co., Schenectady, N. Y.

Mercury Relay—The Vertex Nontilting vertical mercury relay is completely illustrated and described in a new 16-page catalog which is distributed by Dr. F. Loewenberg, 10 East 40th St., New York, N. Y.

Miscellaneous

Wall and Arch Construction—Bulletin 301 gives a complete description of Reintjes wall and arch construction. It is written so that the untrained layman can understand the principles of these designs. Care has been taken to eliminate all theoretical formulae which would tend to confuse the average purchaser. Geo. P. Reintjes Co., 2517-19 Jefferson St., Kansas City, Mo.

Hoists and Gates by Smith—Bulletin 137 presents the essential advantages of Smith Hoist and Gate Equipment. Principal dimensions and capacities are given, where such data is of value, to assist the user in selecting equipment best suited to his particular needs. S. Morgan Smith Co., York, Pa.

Hand Trucks—Bulletin 51 describes and illustrates the standard designs of hand trucks used by industrial plants, warehouses, power plants, packing houses, transportation companies, contractors and institutions. The Fairbanks Co., 399 Lafayette St., New York, N. Y.

Care of Hose—A large useful instruction card on the proper care of rubber hose is designed to be hung in a conspicuous place wherever hose is stored or used. It gives valuable maintenance rules for unpacking, using and storing, observation of which is necessary for long and satisfactory hose service. Instructions are also given for attaching couplings and for the proper use of steam hose, including a table showing temperatures of saturated steam at various pressures. This card is 9 by 11 in. in size. It is being distributed by The Manhattan Rubber Mfg. Division of Raybestos-Manhattan, Inc., Passaic, N. J.

Technical Books—The 150 page spiral bound Catalog No. 5 listing and describing chemical, bacteriological, pharmaceutical, medical, engineering, electrical and general scientific and other technical books of all American and British publishers met with such a great demand that it is now out of print. Catalog No. 6 is now ready and will be mailed to any chemist, engineer, scientist or professor sending 10 cents in stamps or coin to cover mailing. The Chemical Publishing Co. of N. Y., Inc., 148 Lafayette St. New York, N. Y.

Power Plant Construction News

Ala., Birmingham—Tennessee Coal, Iron & Railroad Co., First Avenue North, Birmingham, plans installation with extensions and improvements in coal-mining properties in Docena district. Rotary pumping machinery and auxiliary equipment will be installed. Entire project will cost about $200,000.

Calif., Upland—Old Baldy Citrus Association, East Nineteenth Street, plans installation of power equipment in new one-story addition to fruit-packing plant, 60x160 ft. Proposed to begin work soon. Entire project will cost close to $80,000. W. W. Ache, 301 North Citrus Avenue, Los Angeles, Calif., is architect.

Calif., Vernon—Swift & Co., Union Stock Yards, Chicago, Ill., meat packers, plans installation of electric power equipment in new four-story and basement meat-packing plant at Vernon, near Los Angeles, including improvements in present branch plant at that location. Entire project will cost over $1,000,000. Plans are being completed and work is scheduled to begin soon.

D. C., Washington—Bureau of Yards and Docks, Navy Department, Washington, is securing fund of $500,000, through annual naval appropriation bill, recently approved, for new power plant and equipment in Fourteenth Naval District.

Ill., Roxana—Shell Petroleum Corporation, Shell Building, St. Louis, Mo., plans installation of power equipment, tanks and other mechanical equipment in connection with rebuilding of oil refining plant at Roxana, recently destroyed by fire. Loss reported over $650,000, including equipment.

Ind., Indianapolis—Link-Belt Co., 615 North Holmes Avenue, Indianapolis, plans installation of power equipment in new addition to local plant on South Belmont Street, 280x280 ft. Entire project will cost over $200,000. D. A. Bohlen & Son, Majestic Building, Indianapolis, are architects. Main offices of company are at 307 North Michigan Avenue, Chicago, Ill.

Ind., Indianapolis—F. S. Royster Guano Co., Royster Building, Norfolk, Va., plans power house and pumping station at new commercial fertilizer-manufacturing works on 9-acre tract of land near Kentucky Avenue, Indianapolis, recently acquired. Electric power equipment will be installed for plant operation. Entire project will cost about $500,000. Doeppers Engineering Co., Peoples Bank Building, Indianapolis, is consulting engineer.

Iowa, Fort Dodge—Tobin Packing Co., Fort Dodge, plans installation of power equipment in new addition to meat-packing plant, on which work will begin soon. Entire project will cost close to $100,000.

Iowa, Waterloo—John Deere Tractor Co., Miles Street, plans installation of electric power equipment in new three-story and basement addition, 100x140 ft., to tractor-manufacturing works. Entire project will cost close to $125,000. Work is scheduled to begin soon.

Kan., Kansas City—Spring Valley Butter Co., 2532 Penn Avenue, Kansas City, Mo., plans installation of electric power equipment in new one-story dairy products plant, 135x160 ft., at Reimer Road and Seventh Street Extension, Kansas City, Kan. Cost over $80,000. Charles E. Keyser, 609 Minnesota Street, Kansas City, Kan., is architect.

La., New Orleans—Louisiana Materials Co., Inc., 1510 Julia Street, W. L. Stevens, president, plans installation of power equipment in new concrete pipe-manufacturing plant in vicinity of Industrial Canal, Chief Menteur Highway. Entire project will cost close to $50,000.

Mass., Boston—Bureau of Yards and Docks, Navy Department, Washington, D. C., plans installation of electric power equipment in new addition to structural shop at Boston Navy Yard, for which an appropriation of $731,500 has been authorized.

Mass., Cambridge—J. L. Hammett Co., 290 Main Street, manufacturer of school supplies, plans installation of power equipment in new four-story building, 105x180 ft., for storage, distribution and other service. Entire project will cost about $150,000. Material-handling equipment will be installed. Work will begin at early date.

Minn., Chisholm—City Council has secured approval of PWA for proposed new electric light and power plant, estimated to cost about $290,000, for which financing will be arranged through Federal aid as soon as appropriation is available.

Mo., North Kansas City—Dean Rubber Mfg. Co., Sixteenth and Iron Streets, plans installation of electric power equipment in new one-story addition to mill, 75x113 ft. Cost close to $50,000, with machinery. Work is scheduled to begin soon.

Neb., South Bend—Ak-Sar-Ben Public Power and Irrigation District, Ashland, Neb., Martin Blum, head, now being organized, care of H. H. Henningson Engineering Co., Union State Bank Building, Omaha, Neb., consulting engineer, plans power dam and hydroelectric power plant on Platte River, near South Bend, as part of power and irrigation project to cost $1,500,000. Financing will be arranged through Federal aid.

N. J., Jersey City—National Biscuit Co., 449 West Fourteenth Street, New York, N. Y., plans installation of power equipment in new one-story plant at Broadway and Halleck Avenue, Jersey City, 100x160 ft., where site has been selected. Entire project will cost over $100,000.

N. C., Brevard—Ecusta Paper Corporation, 345 West Fortieth Street, New York, N. Y., Henry S. Strauss, president, recently organized, plans installation of electric power equipment in new pulp and paper mill on Davidson River, near Brevard, for cigarette paper production. Tract of over 200 acres of land has been acquired. A power house will be built. J. E. Sirrine & Co., 215 South Main Street, Greenville, S. C., are consulting engineers.

N. C., Salisbury—Salisbury Coca-Cola Bottling Co., Salisbury, plans installation of power equipment in new local two-story and basement mechanical-bottling works, 170x200 ft. Entire project will cost close to $200,000. Work is scheduled to begin at early date. Temple Snyder is secretary and treasurer.

Ohio, Painesville—City Council, C. S. Fullerton, city manager, has plans maturing for new addition to municipal electric power plant, including installation of additional equipment. No estimate of cost announced. H. Ralph Harlow, 700 Prospect Avenue, Cleveland, Ohio, is consulting engineer.

Okla., Vinita—Frigid Ice Co., Bristow, Okla., has plans for new one-story ice-manufacturing plant at Vinita, 60x90 ft. Cost close to $40,000, with equipment. W. F. Wickham is head.

Texas, Houston—Continental Supply Co., Continental Building, Dallas, Texas, manufacturer of oil well supply machinery, etc., plans installation of electric power equipment in proposed new plant on 10-acre tract of land on Buffalo Bayou, Houston. Entire project will cost over $600,000. Company is a subsidiary of Youngstown Sheet & Tube Co., Youngstown, Ohio.

Va., Hillsville—Carroll Silk Mill, Inc., care of Thomas J. Wallner, president, Virginia Maid Hosiery Mills, Inc., Pulaski, Va., recently organized by Mr. Wallner and associates, plans installation of electric power equipment in new one-story mill at Hillsville. Entire project will cost over $200,000. H. V. Biberstein, 1600 Elizabeth Ave., Charlotte, N. C., is architect and engineer.

Wash., Anacortes—Anacortes Plywood Co., Anacortes, J. J. Lucas, vice-president, plans installation of power equipment in new local plywood mill. Fund of $400,000 has been arranged through a security issue. Proposed to begin work soon.

W. Va., Weirton—National Steel Co., Wheeling, W. Va., plans installation of electric power equipment in proposed new addition to plant at Weirton, to be used as a strip mill unit. Site has been acquired. Entire project will cost over $400,000.

Wis., Bay City—Wisconsin Fabricating Co., 401 South Pearl Street, plans installation of power equipment in new one-story and basement L-shaped plant unit for steel fabricating work. Entire project will cost close to $60,000. Foeller, Schober & Berners, 310 Pine Street, Bay City, are architects.

Wis., Fort Atkinson—Moe Brothers Mfg. Co., 319 East Clybourn Street, Milwaukee, Wis., manufacturer of electric fixtures, plans installation of electric power equipment in new one-story plant, 140x220 ft., at Fort Atkinson. Entire project will cost close to $75,000. Grassold & Johnson, 734 North Jefferson Street, Milwaukee, are architects.